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LARGE CAPACITYMISSILE CARRIER (CMX)

by

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A systems engineering approach to the development of a radically different kind of surface combatant ship is presented, followed by a preliminary design of the ship shown by the analysis to be most effective. The requirement for the project was the development of a ship which would provide a major increase in the missile firepower of a battlegroup. The study conducts an analysis of four warfare scenarios and evaluates the effectivenes of replacing some Aegis ships with the missile carrier (CMX) and examines the relative utility of varying missile loads for the CMX. An alternative is chosen for further development and is designed to the preliminary design level. Data and drawings are included.

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THE LARGE CAPACITY MISSILE CARRIER, CMX

This report documents a systems engineering and design capstone project undertaken by students in the Total Ship Systems Engineering program at the Naval Postgraduate School. The project was under the direction of Prof. C. N. Calvano. (The officer students who comprised the design team were: CDR J. M. Berner; LCDR J.M. Bradley; LT K. A. Torsiello, LT D. T. Hooker, LT C. F. Merrill, all USN.)

ABSTRACT

A tentative operational requirement is given to the development team, calling for analysis and design of a ship (CMX) which acts as the launch platform for large numbers of anti-aircraft and/or cruise missiles, but which does not carry the sophisticated systems required to accurately direct those missiles. The envisioned requirement would have the subject ship serve as a large magazine augmentation for other ships, permitting them to make use of the CMX's missiles. The intent is to increase a battle group's overall effectiveness by increasing its firepower, while decreasing its cost by reducing the number of sophisticated and expensive Aegis control systems.

The report examines four warfare scenarios: land strike; amphibious assault (including theater ballistic missile defense); an engagement against small surface combatants in littoral waters; and a blue water AAW engagement. For each, the degree to which the substitution of CMXs for Aegis ships would improve the effectiveness of a battle group is examined. It is included that the benefits of the large number of additional missiles provided by the CMX more than offsets the lost capability of the reduced number of Aegis systems in the battle group. For each of the first three scenarios, the report concludes that overall battle group effectiveness is increased. For the blue water AAW engagement, effectiveness is decreased if incoming raids are of high density, but increased otherwise.

Upon completion of the scenario analysis, a combat system suite and architecture for the CMX is selected, including a self-defense (but not area defense) capability. Feasibility studies, based on this "payload" proceed, examining propulsion plant options, features for survivability enhancement and general naval architectural considerations. A hull geometry; stability, flooding, structural and weight analysis is provided; ship arrangements are defined; a manning analysis is presented and a cost analysis provided. Numerous examples of calculations, summaries of data and drawings are included.

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I. INTRODUCTION

This paper is the final report for the Total Ship System Engineering (TSSE) student design project for the TSSE class of the summer and fall quarters of 1993. This report represents the compilation of the work performed for the course sequence TS 4002 and TS 4003 during the period from July through December 1993 at the Naval Postgraduate School, Monterey, California. The design products created have been integrated into this design report to provide a detailed and comprehensive record of the work completed.

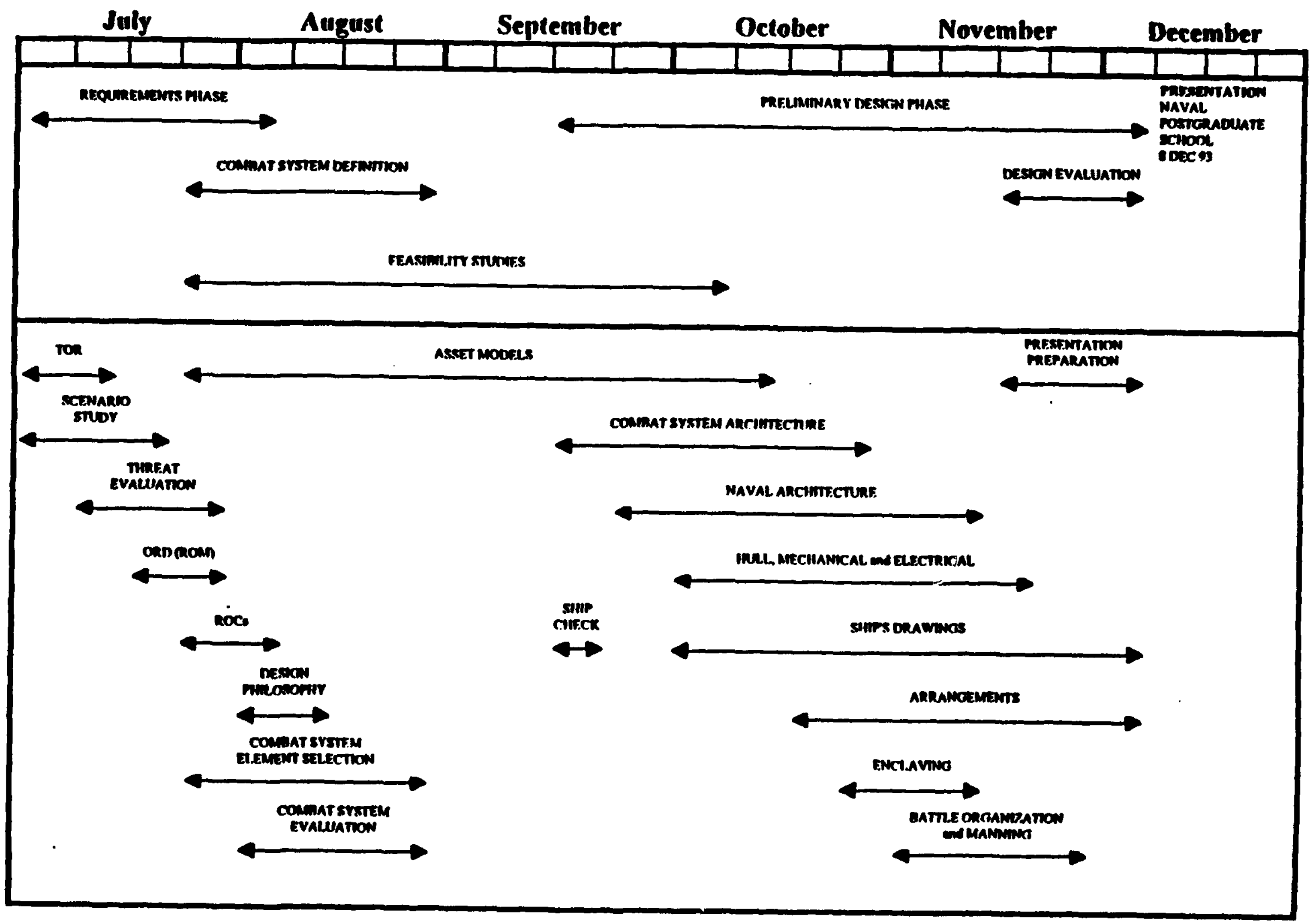
The goal of the design project was to exercise the ship design process from the requirements setting phase through the preliminary design, including design analysis. The subject of the design project was the Large Capacity Missile Carrier, CMX. Although the depth of detail in some areas of the design process were limited due to time and resource constraints, this project included the following design phases:

1. Requirements Phase
2. Combat System Definition
3. Feasibility Study
4. Preliminary Design

The chapters of this report contain the results of these design phases and the supporting information. A documented design history is provided in Appendix X, which outlines the major design decisions and project milestones associated with the design process. Figure 1-1 provides a timeline of the evolutions which occurred during the project.

Figure I-1. Design Timeline

1993



II. REQUIREMENTS PHASE

The Requirements Phase of the ship design process began with the identification of a need that is not met by any ships currently in the fleet. The Faculty Board initiated this phase with a Tentative Operational Requirement (TOR) statement. In it, they briefly described the geopolitical view of the world in the year 2010, and the roles and missions of the US Navy in this environment. The Board further postulated that a "missile carrier" (CMX), might be an effective means for the Navy to meet the challenges ensuing from this assumed global scenario.

The Student Design Team was tasked to develop scenarios for the deployment of the CMX. These scenarios were then used to justify the existence of such a ship, and to support analyses leading to the ship's combat system definition and task group battle performance. Additionally, the Team produced an Operational Requirements Document (ORD) for Faculty Board review. Once approved, the ORD was returned to the Team to proceed with the Feasibility Studies for the ship.

Section A of this chapter includes the TOR statement provided by the Faculty Board. Sections B, C and D are the Scenario Study, ORD and Required Operational Capabilities (ROCs) produced by the Design Team.

A. TENTATIVE OPERATIONAL REQUIREMENTS

1. Background Political/Military World View

Below are the World View, US Navy mission and CMX role descriptions as quoted from the Faculty Board product entitled *Background Political/Military World View (Summer 1993).*

World View, 2010 Time frame

The Former Soviet Union (FSU) is emerging from a turbulent period that lasted from about 1990-2005. Some of the great hopes for the emergence of democracy and open markets in the FSU are beginning to dim. After the initial breakup of the USSR, there was a period of liberalization. Many economic reforms were enacted and a social federation of the former republics was emerging. But more recently, the strong centralizing tendencies of the Russian past have begun to re-assert themselves. The Russian republic is clearly the premier republic in the federation and is beginning, more and more, to dictate policy. New Russian leaders are dissatisfied with their role in shaping and participating in the new world order. The world appears to be on the brink of a new round of the old cold war.

However, in the interim between the old cold war and the new Russian ascendancy, India and China have emerged as world powers second only to the United States and the re-emerging Russian federation. The world has witnessed the emergence of former third world countries as significant regional powers. Regional conflict and small, localized, but persistent, wars have been frequent. Racial and religious hatreds seem to spring up like weeds and show no sign of abating. The Middle East remains a powder keg; the Balkans have been the scene of revolving conflicts with the identities of foes and allies frequently changing. Wars among nations in Africa are almost commonplace.

It appears the world is forming into three "camps." The Russian-led federation of most of the former Republics appears to be headed for an alliance with the Moslem Fundamentalist League. The US and a number of Pacific Rim nations are emerging as a countervailing grand alliance. Western Europe and China are concerned about the apparent emergence of a new cold war, but seem to want to assume the roles of neutrals, with Europe willing to assert its military powers only in containing the continuing Balkan conflicts. China continues to be largely inward-focused, intent on condoling its own vast population and territory, while slowly strengthening its military technology.

US Navy Role

Against this world background, the US Navy will continue to require the ability to:

- Operate in a forward deployed mode, far from US shores, for lengthy periods of time. (The Pacific Ocean, with its vast distances, has become the primary sphere of Navy concern and the scene of most Navy operations. The new US-Russian confrontation seems to have a Pacific axis, rather than the European one of the old cold war.)
- Project power ashore via tactical air power and cruise missiles.
- Conduct opposed amphibious assaults.
- Defeat a re-emerging Russian (ex-Soviet) Navy at sea.
- Protect US interests and US nationals worldwide.

After passing through a period when the US had no credible blue-water competitors, the world is changing again. The recently increased USN capabilities for littoral, third world, operations will continue to be needed. But much of the lost open ocean superiority must be re-asserted. The Navy is responding with a number of ship, submarine and weapons programs. One of those under consideration is a "Large Capacity Missile Carrier", tentatively designated the CMX (Carrier, Missile, X). The CNO has recently issued the tentative requirements document for such a ship.

2. Large Capacity Missile Carrier (CMX) 2010

The following is quoted from the Faculty Board product entitled *Large Capacity Missile Carrier, CNO Tentative Operational Requirement (Summer/Fall 1993)*.

With the drawdown of naval combatants, the number of surface combatants available for use in task groups will be decreasing. This means fewer task groups deployed at one time or a decrease in capability of those task groups that are deployed. An alternative is to increase the magazine capacity available to the task group without increasing the number of surface combatants. Increasing the magazine capacity on existing surface combatants is not a viable option. However, providing a low cost ship which can act as a magazine for the available surface combatants may be. What is envisioned is a "missile carrier" that acts as a launch platform for a large number of anti-aircraft and/or cruise missiles but does not carry the sophisticated (and costly) detection and control elements needed to employ all these weapons itself. For SM-2 missiles used in their normal task group AAW role, the Off-board Controlled Casualty Launch System planned for DDG 51 Flight III ships allows AEGIS ships to utilize an off-board launcher. A similar approach could handle SM-2 Block 4A missiles used for tactical ballistic missile

defense. For other missiles -- Tomahawk, Harpoon, ASROC -- the "missile carrier" would carry the necessary fire control and navigation equipment but would depend on off-board assets (other tactical units or National assets) for target detection and localization. The number of missiles carried should be determined on the basis of incremental ship cost and the configuration needs of future task groups.

Whenever a threat may exist, the "missile carrier" would sail as part of a task group or would be escorted by a surface combatant. Hence its self-defense capabilities would be limited to dealing with air and underwater threats (torpedoes) which get past the surface combatant(s), small craft which the surface combatant(s) may be too busy to attack, and mine avoidance. Provisions for an onboard helo should be limited to a single gun ship and that, only if the associated cost is low. This implies that: (a) its point defense AAW systems would not include SM-2 missiles, (b) Its air surveillance capability need be no more than that required by the installed point defense AAW capability, (c) its surface surveillance and ASUW capability would be limited to the horizon and (d) its ASW capability would be limited to torpedo countermeasures.

The ship's speed and endurance should be as required to maintain PIM with carrier and amphibious task groups. It should be capable of extended forward deployment and operation in areas of regional conflicts.

B. SCENARIO STUDY

Several different scenarios for which a "missile carrier", or CMX, could be employed, were developed from those quoted in the TOR:

- Blue water engagement against a resurgent Russian Empire and Moslem Allies
- Small combatant engagement
- Support of amphibious landing
- Theater Ballistic Missile Defense (TBMD)

The Design Team developed four scenarios to analyze the efficacy of a CMX design. These were closely related to those provided by the faculty but reoriented to enable analysis of specific mission tasks. The four scenarios were:

- Land Strike
- Amphibious Assault (including TBMD)
- Blue Water Engagement
- Small Combatant Engagement

Each of the four scenarios is described in the following sections. To develop them, "standard" ship battlegroup configurations were defined for both present (1995) and future (2010) time frames. These configurations are as shown in the following table:

Table 2-1. Battlegroup Configurations

	Platform	Present (1995)	Future (2005)
US CVBG	CVN	1	1
	CG	2	1
	DDG	4	2
	SSN	2	1
	CMX	0	1
US SSG	CG	1	0
	DDG	1	1
	CMX	0	1
US ATF	LPD/LHA/LHD	2	1
	LX	0	1
	LST	1	1
	LSD	1	0
	CG	1	0
	DDG	2	1
	CMX	0	1

As each scenario was developed, the effect of adding one or more CMX or replacing platforms with a CMX was evaluated. At this point in the design, the CMX was little more than a collection of VLS cells grouped together at one point. No estimates were made of the displacement, speed, propulsion plant or auxiliaries. The combat system was not defined, except to say that it did not have SPY1 or a successor radar and that the ship can receive offboard commands to control the missiles it carries. This stage had two goals. The first was to determine if there were any credible scenarios that would show a benefit to having a CMX, and the second, to lay some ground work for determining the size of the CMX.

1. Land Strike Mission

Long range cruise missiles launched from ships and submarines against land targets are the high technology weapon of choice in the "new world order" for situations ranging from sanction enforcement to conventional warfare. During the 1991 Persian Gulf war, 288 Tomahawk cruise missiles were launched from US Navy ships against fixed targets in Iraq. In January 1993, another 45 Tomahawk cruise missiles were fired at suspected Iraqi nuclear facilities; and, in June 1993, 23 more were fired from a US Navy cruiser in the Persian Gulf and a US Navy destroyer in the Red Sea, at the Iraqi intelligence headquarters near Baghdad. These recent events underscore the value of the sea-launched cruise missile, in low intensity, littoral conflicts.

Cruise missiles launched from warships act to complement carrier-based and land-based tactical air power. Employed as a first strike weapon, cruise missiles can be effective in clearing enemy AAW defenses and disrupting enemy command, control, and communications in preparation for conventional tactical air raids. In areas remote from land based air assets, employment of tactical air power requires the presence of an aircraft carrier. However, employing ship launched cruise missiles for such missions allows aircraft carriers to operate on longer tethers from the world's hot spots and other areas of strategic interest. Moreover, cruise missile attacks add political flexibility in the use of such force since pilot casualties can be reduced.

The ability to support the high operating tempo of numerous carrier battle groups has been somewhat improved due to the versatility of surface action groups which now have a limited

strike capability. Thus, US surface combatants which are capable of launching cruise missile attacks have assumed a conventional deterrence role.

One obstacle to the employment of strike capable Surface Action Groups (SAG), referred to as Surface Strike Groups (SSG), is the limited number of cruise missiles carried by current cruisers and destroyers. AEGIS cruisers (CG 52 and newer classes), can carry a total of 122 anti-air, anti-ship, or land attack cruise missiles. DD 963 class ships fitted with vertical launch systems (VLS) can carry a total of 61 missiles, and DDG 51 class ships can carry a total of 90 missiles. However, because these vessels must also carry self-defense assets, there is obvious competition for VLS cell space among SM-2 AAW missiles, Tomahawk cruise missiles, and other planned weapons such as vertically launched ASROC and Sea Sparrow close-in AAW missiles.

Tomahawk capable attack submarines (SSN) can also support the land attack mission. However, the long range cruise missile land attack is an adjunct to the primary missions of the SSN. Since the SSN is a relatively expensive cruise missile launch platform, and the SSN force levels will probably continue to decrease in the near future, land attack from SSNs will probably continue to be a secondary mission.

The January and June (1993) cruise missile attacks on Iraq would have severely depleted the strike capability of any current two ship SSG. Because of this limitation, it might be necessary to locate a carrier battle group near the SSG operating area if further hostilities are expected. However, with continued downsizing in both fleet units and personnel, adding ships to the SSG composition is not desired, and it will become more difficult to quickly position carrier battle groups since there will be fewer of them operating. Clearly, increased missile magazine capacity is required for the future SSGs.

a. Assumptions

Vertical launch systems can fire SM-2 AAW missiles, Tomahawk cruise missiles, and planned versions of ASROC, Sea Sparrow and Harpoon missiles. A probable missile loadout for current VLS equipped ships is shown in Table 2.2.

Table 2-2. VLS Missile Loadout

Ship Class	AAW Missiles (SM-2)	ASW Missiles (ASROC)	Land Attack Missiles (Tomahawk)	Total Number of VLS Missiles
CG 52+	74	8	40	122
DDG 51	54	8	28	90
DD 963	0	8	45	61

Given this loadout, a two ship SSG would possess the following land attack strike capability:

SSG Composition	Total Number of Land Attack Cruise Missiles
2 DDG 51	56
2 CG 52+	80
2 DD 963	90
1 CG 52+ and 1 DDG 51	68
1 DDG 51 and 1 DD 963	73
1 CG 52+ and 1 DD 963	85

A standard CMX missile loadout was postulated as having 50% Tomahawk cruise missiles, 40 to 50% SM-2 AAW missiles, with the remainder possibly being an improved self-defense AAW missiles. The possible missile loadouts for the various proposed versions of CMX ships include the following table:

Table 2-3. CMX VLS Missile Loadout

CMX Variant	Number of VLS	SM-2 AAW Missiles	Tomahawk Cruise Missiles	Point Defense Missiles
v3	3	73	92	72
v4	4	104	122	72
v5	5	135	152	72
v6	6	165	183	72
v7	7	195	214	72
v8	8	226	244	72

Based on these CMX configurations, future SSGs will likely be made of one AEGIS ship and at least one CMX. This combination gives the SSG a total land attack cruise missile loadout within the range shown in the following table:

SSG Combination	Tomahawk Cruise Missiles
DDG plus CMX v3	120
CG plus CMX v3	132
DDG plus CMX v4	150
CG plus CMX v4	162
DDG plus CMX v5	180
CG plus CMX v5	192
DDG plus CMX v6	211
CG plus CMX v6	223
DDG plus CMX v7	242
CG plus CMX v7	254
DDG plus CMX v8	272
CG plus CMX v8	284

b. Scenario

United Nations weapon inspectors have become increasingly frustrated with the lack in progress in their monitoring of suspected Iraqi nuclear and chemical weapons plants. Stalled inspections, outright confrontation with inspectors and news media , and painfully slow United Nations negotiations have precluded the inspection of five sites which are alleged to be part of an accelerated Iraqi program to build nuclear warheads for use on an improved, longer range SCUD missile. US national asset intelligence sources have indicated possible shipments of warhead grade uranium and plutonium from China to Iraq. Saddam Hussein has scheduled an international press conference to be held in 48 hours. Reports, apparently leaked from the US Central Intelligence Agency and National Security Council staffers, have made headlines in both the Washington Post and New York Times: "Nuclear Armed Saddam Prepares Ultimatum".

In recent months, given higher than anticipated budget deficits and the stalled national economy, the beleaguered US president had ordered his Defense Secretary to cut an unprecedented $10 billion dollars from the *current* fiscal year defense budget. The result of this drastic funding cut leaves the US Navy with only ten carrier battle groups (CVBG). Previous fiscal year cuts have begun to impact maintenance schedules and operating tempo. Readiness reports have become bad news. Two CVBGs are currently deployed: one to the western Mediterranean Sea and one to the western Pacific Ocean. The Mediterranean CVBG stands ready to surge into the Atlantic Ocean to support UN peacekeeping troops in Nigeria. The WestPac CVBG is in the Sea of Japan, flexing muscle in support of talks with North Korea concerning nuclear non-proliferation. A two ship surface strike group (SSG) is stationed in the Persian Gulf and Straits of Hormuz.

The Chairman of the Joint Chiefs of Staff (JCS) has proposed a Tomahawk cruise missile attack from the Persian Gulf SSG. The CVBGs are out of range to respond within the required time frame. Tactical air strikes by US Air Force (USAF) bombers have been "shot down" by the European Community via NATO: Denial of landing and fueling flights in support of bombers and denial of air space overflight (France) effectively vetoed the USAF option.

The SSG plan is based on a swift, surprise, stealthy strike against the five suspected nuclear weapons sites in Iraq. The plan calls for twelve Tomahawk cruise missiles to be targeted against each of the five nuclear weapons sites, for a total of sixty cruise missiles. These missiles are to be launched in a first strike within the next twenty four hours. Based on current intelligence reports, the proposed strike should encounter limited AAW fire in the vicinity of the suspected nuclear plants. The magnitude of this first strike is based on this limited AAW

capability and provides for sufficient firepower to quickly neutralize nuclear weapons production. National assets have been redirected and programmed to provide bomb damage assessment (BDA) within four hours of the planned first strike. Additional strikes will be performed as necessary to assure destruction of any potential nuclear weapons.

The timeline for this hypothetical scenario unfolds as follows, where T=0 is the time scheduled for the expected apocalyptic Iraqi press conference, and times are shown in minus hours from that event:

T-48 Iraqi spokesman schedules international press conference for T=0.

T-40 President meets with NSC to approve JCS attack plan.

T-36 US Navy SSG launches Tomahawk attack per JCS plan against suspected Iraqi nuclear facilities, 60 missiles fired.

T-32 US satellite BDA reveals 3 of 5 Iraqi nuclear sites destroyed.

T-31 Additional BDA reveals intense activity at four semi-mobile SCUD launch sites, each within a twenty mile radius of the partially damaged nuclear weapons plant sites.

T-29 Updated Tomahawk missile terrain maps transmitted to Persian Gulf SSG.

T-27 Second Tomahawk strike consisting of 40 missiles launched as follows: 4 each against the two remaining, partially damaged nuclear weapons plants; 8 each against the semi-mobile SCUD launcher sites.

T-23 Satellite BDA confirms destruction of all weapons plants; two semi-mobile Scud launch sites appear to remain functional; four SAM sites in vicinity of the two remaining SCUD launch sites show major activity.

T-21 New Tomahawk terrain map data transmitted to Persian Gulf SSG.

T-20 CNN transmits impromptu new conference with Saddam. He announces that in response to US aggression against Iraqi sovereignty, a Holy War of revenge will be launched against Israel and the West.

T-19 Third Tomahawk attack launched against two SCUD launch sites and four surrounding SAM sites. Attack methodology: Initial strike of 24 cruise missiles against the SAM sites (6 missiles each). Second wave strike of 16 Tomahawk cruise missiles against two remaining SCUD launch sites.

T-15 Satellite BDA confirms destruction of all nuclear weapons plants and semi-mobile SCUD launcher sites.

T-0 Iraqi Foreign Minister, announces that Iraq will comply with UN resolutions concerning nuclear weapons.

Scenario Missile Summary: 140 Tomahawk cruise missiles fired at 13 Iraqi fixed targets.

c. Evaluation

The table below shows the various SSGs and the remaining missile balance after completion of the Iraqi strike scenario. Without carrier based tactical air power, current two-ship SSGs (the first three entries in the table) do not carry sufficient cruise missiles to successfully execute small-scale land attack against modern adversaries such as Iraq in the above scenario. The Iraqi scenario is presented as a plausible land strike mission which naval forces might need to execute in preserving the new world order.

Table 2-4. Land Strike Scenario

Ship Composition of Surface Strike Group (SSG)	Tomahawk missiles available after Iraqi Land Strike Scenario
2 DDG 51	-84
2 CG 52+	-60
2 DD 963	-50
1 DDG 51 and 1 DD 963	-67
1 CG 52+ and 1 DDG 51	-64
1 CG 52+ and 1 DD 963	-55
DDG plus CMX v3	-20
CG plus CMX v3	-8
DDG plus CMX v4	10
CG plus CMX v4	22
DDG plus CMX v5	40
CG plus CMX v5	52
DDG plus CMX v6	71
CG plus CMX v6	83
DDG plus CMX v7	102
CG plus CMX v7	114
DDG plus CMX v8	136
CG plus CMX v8	148

An incomplete conventional attack would probably result in increased tension levels which could actually accelerate the commencement of hostilities by a would-be aggressor. In the Iraqi strike scenario above, a limited nuclear strike could have been launched by Iraq against Israel at time T-16 hours from the two remaining semi-mobile SCUD launch sites. Such a nuclear attack would probably, at the very least, result in an expansion of the conflict beyond the local region. Thus, the US needs to maintain the military force necessary to pre-empt such nuclear attacks. Conventional weapons such as ship launched cruise missiles appear to offer an effective means to swiftly disarm any would-be international nuclear aggressor. However, these weapons must be employed in sufficient quantity and in repeated strikes until bomb damage assessment verifies total destruction of the enemy's capital forces. The proposed CMX class has the potential to provide the necessary quantity of ordnance on target.

For the land attack mission, a new CMX ship class along the line of variants v5 through v8 appears to present a reasonable and necessary capability for naval surface strike groups. These CMX variants allow for SSG compositions which can execute the Iraqi strike scenario and still have margin for unexpected additional strike or AAW requirements. The larger CMX ships with more VLS modules are obviously more capable than the smaller versions, but two factors may limit the size of the CMX: higher ship procurement cost; and, increased vulnerability for other engagement scenarios (such as a high intensity blue water battle) as the ship size is increased due to more VLS installations. Later studies investigate the tradeoffs for the upper limit size for the CMX.

This scenario did not consider the addition of the CMX to a current surface strike group. The CMX is proposed as a lower cost alternative to future AEGIS platforms with relatively expensive sensors, computers, and crews. Also, the scenario for long-term, but very-low-engagement-rate, littoral water, land strike operations was not investigated, but the results are expected to confirm that for these land strike scenarios, surface strike groups are not limited by the number of sensors, but rather by the number of missiles in the strike group's magazines. Finally, while certain sizes (i.e., missile capacities) of the CMX ship may appear to be optimum for the land strike mission, there will be tradeoffs when other scenarios are considered.

2. Amphibious Assault

The tactical employment of US Navy surface combatants and submarines in the role of Land Strike is also essential in an Amphibious Assault. The functions of cruisers and destroyers in providing gun fire support (NGFS) and defense of the Amphibious Operation Area (AOA) can be expanded through the use of land attack, anti-air and anti-ship cruise missiles.

As in the land strike mission, cruise missiles can complement the air attack and reduce losses of aircraft and personnel. The extended range of the cruise missiles would allow the Amphibious Task Force (ATF) to launch the first strike at a greater distance from the beach, reducing the opportunity for enemy retaliation. Once secured, control of a larger AOA (inland, seaward and the surrounding airspace), can be accomplished. However, the limited cruise missile loadout capacity of cruisers and destroyers limits the viability of an expanded mission such as an amphibious assault. Employment of the CMX would provide additional cruise missile capacity, which would significantly reduce this limitation.

This scenario provides an analysis of the mission capabilities of the ATF in its present conventional configuration and the effects on its capabilities of the employment of the CMX to augment the ATF, or to reduce the number of cruisers/destroyers required to accomplish its mission.

In addition, the ATF will also have to defend itself from tactical ballistic missiles launched in response to the amphibious landings. Third world countries presently have and will continue to acquire these types of weapons.

a. Assumptions

A standard probable missile loadout for the current VLS ships to be used in an ATF battle configuration, is as shown below:

Ship Class	AAW Missiles (SM-2)	ASW Missiles (ASROC)	Land Attack Missiles (Tomahawk)	Total Number of VLS Missiles
DDG 51	54	8	28	90
CG 52+	74	8	40	122

The US Naval ATF, configured for a third world amphibious landing operation is assumed to consist of the following units[1]:

ATF Composition	Present (1995)	Future (2010)
LPD/LHA/LHD	2	1
LX	0	1
LST	1	1
LSD	1	0
CG 52+	1	0
DDG 51	2	1
CMX	0	1

1. Configurations incorporate employment of the LX class ship in future ATFs along with the CMX.

Considering only the missile capabilities of the DDG 51 and CG 52+ ships, the ATF would have the following loadout capacities:

ATF Composition	AAW Missiles (SM-2)	Land Attack Cruise Missiles (Tomahawk)
1 CG 52+ and 2 DDG 51	182	96

Proposed VLS missile loadout for an amphibious assault may consist of 50% Tomahawk cruise missiles and 40% SM-2 AAW missiles with the remaining 10% Sea Sparrow (or future variant point defense weapons not to exceed 18 cells for larger CMX variants). It is also postulated that a Naval variant of the Army Tactical Missile System (ATACMS), configured for vertical launch, may be available by 2010, and would be employed similarly to the Tomahawk missile. Based on this postulated loadout, missile capacities of the CMX variants are as follows:

CMX Variant	Number of VLS	SM-2 AAW Missiles	Tomahawk Cruise Missiles or ATACMS	Point Defense Missiles
v3	3	73	92	72
v4	4	104	122	72
v5	5	135	152	72
v6	6	165	183	72
v7	7	195	214	72
v8	8	226	244	72

Future ATFs are assumed to employ one AEGIS ship and at least one CMX, giving the ATF the following capacities:

ATF Configuration	SM-2 AAW Missiles	Tomahawk Cruise Missiles or ATACMS
DDG plus CMX v3	127	120
CG plus CMX v3	147	132
DDG plus CMX v4	158	150
CG plus CMX v4	178	162
DDG plus CMX v5	189	180
CG plus CMX v5	209	192
DDG plus CMX v6	219	211
CG plus CMX v6	239	223
DDG plus CMX v7	249	242
CG plus CMX v7	269	254
DDG plus CMX v8	280	276
CG plus CMX v8	300	288

Also, for this scenario, it was assumed that the SM-2 of the future would provide a Tactical Ballistic Missile Defense (TBMD), with capabilities similar to that of the Patriot Missile. The envelope of engagement for this SM-2 is an altitude up to 100,000 feet and a range out to 20 nautical miles.

The objectives of the ATF are to establish the AOA by securing:

- A 25 square mile land area (5 mile along beach front, 5 mile penetration into surrounding areas).
- The area seaward extending 25 nautical miles.
- An airspace within 50 mile radius of the beachfront.

- Land approximately 2400 troops and support equipment on the beach front.

The following potential targets are to be destroyed during the first strike and during ship movement:

- Beachfront area
- Command centers
- Communications equipment/radars
- Armored formations

The following threats may be encountered during the development of the scenario:

- Sea (patrol boats, anti-ship missiles)
- Air (patrol or attack aircraft, anti-ship missiles)
- Land based (guns, anti-ship missiles, ballistic missiles)

b. Scenario

The scenario for the Amphibious Assault was developed as follows:

(1) The ATF approach to the AOA vicinity was unopposed until first offensive strike.

(2) The ATF initiated the first land strike on twenty land based targets. The land strike began with Tomahawk cruise missiles or ATACMS launched at a range of 50 nautical miles from the beach. Ten cruise missiles were used against each land based target. As the land strike continued, the ATF units closed the beach front area and secured the seaward areas to establish the AOA.

(3) Upon commencing the land strike, the ATF defended against sea and air threats. SM-2 missiles and ships' point defense systems were employed against incoming patrol aircraft and anti-ship missiles launched from the aircraft. Ten patrol aircraft attacked the ATF, each launching two anti-ship missiles at different units in the ATF (totaling twenty anti-ship missiles). Two AAW missiles were expended in destroying each patrol aircraft and anti-ship missile. As the ATF units closed within 25 miles of the beach, anti-ship missiles launched from patrol boats were defeated. Five patrol craft, firing two missiles each, were encountered (totaling ten anti-ship missiles). Two more SM-2s were expended for each patrol boat and anti-ship missile.

(4) Upon securing the AOA, the ATF defended against land based ballistic missiles. Once the ATF units had closed the beach front areas, troops and equipment were moved ashore and the remaining areas of the AOA were secured. Land based ballistic missiles were then launched at the beach front and seaward areas of the AOA. Thirty missiles were fired at units in the ATF, from a range of up to 500 miles. In response, two SM-2s were employed against each ballistic missile in defense.

(5) Over the following two weeks, repeated enemy attempts to regain control over portions of the of the AOA were made using aircraft, patrol boats and ballistic missiles. Ten patrol aircraft, five patrol boats and twenty ballistic missiles were encountered. In addition, ten new land targets were uncovered by intelligence.

SM-2 and Tomahawk missiles were used in similar proportions similar to that described above.

c. Evaluation

As shown in the table below, current ATF configurations do not carry a sufficient loadout to support the amphibious assault scenario developed. Tactical employment of the CMX in these configurations improves the capability of the ATF.

Table 2-5. Amphibious Assault Scenario

ATF Configuration	Remaining SM-2s	Remaining Tomahawks or ATACMS
1 CG 52+ and 2 DDG 51	-98	-204
DDG plus CMX v3	-153	-180
CG plus CMX v3	-133	-168
DDG plus CMX v4	-122	-150
CG plus CMX v4	-102	-138
DDG plus CMX v5	-91	-120
CG plus CMX v5	-71	-108
DDG plus CMX v6	-61	-89
CG plus CMX v6	-41	-77
DDG plus CMX v7	-31	-58
CG plus CMX v7	-11	-46
DDG plus CMX v8	0	-24
CG plus CMX v8	21	-12

Based on the above table, the future ATF would require a CMX larger than variant v8, or at least two v6 variants, to have a sufficient number of missiles available to support this engagement.

3. Blue Water Engagement

With the resurgence of Russia as a hostile power, the possibility that the US Navy will be faced with blue water engagements arises. With a smaller base force, the availability of smaller escorts will be severely diminished. Additionally, the number of cruisers will also be significantly reduced, due to the retirement of all classes except AEGIS. Thus the total number of platforms, missiles and directors will be much smaller than today, and the possibility exists that a task group could exhaust its missile supply. The reduction of available missiles plus the development of the Cooperative Engagement Capability (CEC) introduces the possibility that in certain scenarios, the deployment of an inexpensive missile carrier could help to make up for the reduced availability of other platforms. One of these scenarios is a blue water engagement.

a. Assumptions

Commercial software for a naval battle simulation computer game, entitled Harpoon™, manufactured by Three Sixty, Inc., was used to analyzed the blue water scenario. Some of the assumptions for this scenario, such as ship types and weapons employed, were taken from the information provided by the software documentation and instruction books, and are part of the simulation program.

The blue water scenario postulated that a US Carrier Battle Group (CVBG) had been deployed to oppose a Russian Republic Navy (RRN) SAG. The US CVBG was within range of

land-based RRN strike aircraft and the US force had been detected by RRN forces. RRN forces had identified the CVN and had launched an attack, intending to concentrate on taking the aircraft carrier out of action.

The primary US force objectives were to engage an RRN amphibious force that threatened Iceland and to control the battlespace around the CVBG. The RRN had mustered the following forces to screen the amphibious assault with the primary ASUW weapons as shown:

Platform	Number	ASUW Missile	Range (nm)	Number	PK
Kirov	1	Shipwreck	250	20	0.8
Slava	2	Sandbox	300	16	0.8
Sovremennyy	2	Sunburn	65	8	0.8
Udaloy	3	NA	NA	NA	NA
Krivak	3	NA	NA	NA	NA
Sierra	1	NA	NA	NA	NA
Oscar	1	Shipwreck	250	24	0.8
Backfire	24	Kitchen	250	72	0.7
Badger	24	Kitchen	250	48	0.7

For the future war (2010) the following CVBG was deployed: one CVN, two AEGIS VLS cruisers and two DDG 51s. For the present day CVBG the following ships were selected: one CVN, two AEGIS VLS cruisers, three DDG 51s and one Kidd class DDG. The number of Anti-Air Warfare (AAW) missiles for each platform were estimated. The missiles brought to the battle by the air wing were tallied separately. Each of the six CMX variants were also listed. An Evolved Sea Sparrow system was assumed to have been developed. This system will be discussed later in this study. The parameters for missile ranges and probability of kill (Pk) were

drawn from open sources. The naval combat simulator Harpoon™ was used to model the present day battlegroup response to the Russian missile attacks. The scenario was then evaluated with several different configurations of CMX. The number of Evolved Sea Sparrow missiles were held constant as the CMX size was scaled. The number of SM-2s was allowed to vary with size.

Platform	AAW Missile	Range (nm)	Number	PK
Nimitz	NATO Sea Sparrow	10	24	0.6
Ticonderoga VLS	SM-2 Block II	50	74	0.8
	Evolved Sea Sparrow	10	32	0.75
DDG 51 IIA	SM-2 Block IV	60	54	0.8
	Evolved Sea Sparrow	10	32	0.75
F-14D	AIM-54 Phoenix	110	2	0.55
	AIM-7M Sparrow	24	4	0.55
	AIM-9R Sidewinder	10	2	0.75
F/A-18	AIM-7M Sparrow	24	4	0.55
	AIM-9R Sidewinder	10	4	0.75
CMX v3	SM-2 Block IV	60	73	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v4	SM-2 Block IV	60	104	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v5	SM-2 Block IV	60	133	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v6	SM-2 Block IV	60	165	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v7	SM-2 Block IV	60	195	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v8	SM-2 Block IV	60	226	0.8
	Evolved Sea Sparrow	10	72	0.75

The missiles available to the Battlegroup had been classified as long or medium range. Short range (e.g. Stinger missiles) had not been evaluated. Long range was defined as greater than 15 miles, medium range was defined as greater than 2 miles but shorter than 15 miles. The following table summarizes the long and medium range missiles available to the Battlegroup at full load.

Platform	Number	Total Long Range Missiles	Total Medium Range Missiles
Nimitz	1	-	24
Ticonderoga VLS	2	148	64
DDG 51 IIA	2	108	64
F-14	24	48	144
F/A-18	24	-	192
CMX v3	2	146	144
CMX v4	2	208	144
CMX v5	2	270	144
CMX v6	2	330	144
CMX v7	2	390	144
CMX v8	2	452	144

The complete weapons suite modeled for each ship is detailed in Appendix A.

b. Scenario

Over the past several years, fishing in the North Atlantic around Iceland has been severely depressed. Icelandic fishing vessels have journeyed far and wide to sustain their fishing industry. Northern waters have been fairly fruitful, but have led to conflicts with Russian authorities. Several Icelandic vessels have been seized by the Russian Republic Navy. Three weeks ago, four

vessel were seized near Russian territorial waters. In retaliation, Denmark closed the Skagerrak to all Russian flag shipping. Twelve days ago, a RRN Krivak attempted to send a boarding party aboard a fishing vessel that was clearly in international waters. The crewmen responded with small arms fire, killing several of the boarding party. A nearby Norwegian destroyer and the Krivak then traded gunfire. Both vessels were damaged severely but returned to port. US national assets have detected large numbers of RRN vessels under way. The Russians have informed NATO of a "scheduled" naval exercise in the vicinity of Jan Mayen Island. They have also insisted that Iceland pay reparations for the damaged frigate. A Russian amphibious task force was reported underway by Norwegian patrol boats, shortly before contact was lost with them.

The United States has had declining relations with the Russian Republic. The Russian Ruler, Alexander Chekhov, has endeavored to restore the Russian empire. Over the past several years Russia has forcibly returned several Republics to the empire, while most of the world has stood idly by. Following the detection of Russian preparation of an amphibious force, a CVBG was deployed to Norwegian waters. Three days ago, Russian aircraft overflew the CVBG. Over the past several days, the Russians have made preparations to attack the CVBG.

Over the past several hours many feints have been made to force the US BG Commander to deploy fighters. Missile attacks will be launched from the RRN SAG as detailed above, an Oscar SSGN, and land based aircraft. The missile launches from the SAG and Oscar will be coordinated to arrive as simultaneously as possible.

The naval combat simulator, Harpoon™, was used to measure the effectiveness of the present day battlegroup. In the simulation, the RRN SAG was located approximately 225 miles

north of, and the Oscar was located approximately 100 miles to the south of the US CVBG. The airstrike was comprised of successive waves of land based aircraft, all attacking from the east. The US CVBG had launched all available Combat Air Patrol (CAP), but took no offensive action until the first Red unit was detected. Since the simulation did not allow the prepositioning of aircraft at game start, there was a forced delay in accomplishing the airstrike. The artificial intelligence, simulating the Blue force, launched attacks against the RED forces as soon as they were detected. This further required separating surface and submarine attacks from the air strike. The scenario was refined until a strike size was determined that sank the carrier approximately 25% of the time.

A numerical study was then conducted to evaluate the performance of the battlegroup with CMX attached and with the CMX as a replacement for one or more DDGs.

c. Evaluation

Using Harpoon™, the US CVBG described above was shown to be capable of defending itself from an initial attack of 24 Surface to Surface (a mixture of Shipwreck and Sunburn) missiles from the SAG and 20 Shipwreck missiles launched from the Oscar, followed approximately one hour later by three waves of missiles from land based aircraft consisting of a wave of 24 AS-6 Kitchen missiles in high altitude flight, a wave of 72 AS-6 Kitchen missiles in high altitude flight and a final wave of 48 AS-6 Kitchen missiles in sea skimming mode for a total of 188 missiles.

Once it was determined that the CVN had survived the encounter a numerical study was performed. Since the data required to conduct a numerical analysis of the Harpoon™ simulations

was not available, the Design Team developed a set of threat weapon models (see Appendix B). In addition, the following assumptions were made:

(1) Threat missiles are co-located;

(2) AEGIS platforms can launch a missile every second;

(3) A 0.1 second time delay exists between missile end of flight and the associated illuminator slewing to the next missile;

(4) AEGIS platforms can have 16 missiles in flight at one time;

(5) Minimum SM-2 effective range is 4 miles;

(6) SM-2 has a PK of 0.7 versus the threat missile anywhere within the SM-2's engagement envelope;

(7) Two SM-2s are fired at each incoming missile;

(8) Friendly air assets were not modeled.

The table below summarizes the performance of a single AEGIS platform in a high threat environment (see Appendix C):

Threat Missile	Maximum Engagement Range	Maximum Missiles Engaged	Number of Leakers	Total SM-2s Expended
Takeover (High Flier)	178	32	2.88	64
Seagull (Sea Skimmer)	15	29	2.61	58

The table below summarizes the expected battlegroup SM-2 missile consumption:

Threat Missile	Maximum Missiles Engaged	Number of Leakers	Total SM-2s Expended
Takeover (High Flier)	140	12.6	280
Seagull (Sea Skimmer)	48	4.32	96

Also calculated was the expected SM-2 inventory for the nominal battlegroup with one CMX of each variant type added. It was assumed that one quarter of all SM-2s expended came from the CMX, except for the case with CMX v3, where the CMX runs out before the end of the engagement. The following table summarizes the remaining SM-2 inventory for the nominal battlegroup.

Battlegroup Composition	Total Long Range Missiles Remaining	Long Range Missiles Remaining On CG and DDG	Long Range Missiles Remaining On CMX
Nominal-CVN, 2 CG, 3 DDG 51, 1 DDG 993	66	66	-
Nominal with CMX v3	159	159	-21
Nominal with CMX v4	190	180	10
Nominal with CMX v5	221	180	41
Nominal with CMX v6	251	180	71
Nominal with CMX v7	281	180	101
Nominal with CMX v8	312	180	132

The condition where two CMXs replace one of the DDGs and one of the CGs was also studied. This condition reaches saturation more rapidly due the reduction in the number of target illuminators. As this battlegroup was not capable of being modeled in Harpoon™, only a numerical study was performed. In this scenario, it was assumed that fifty percent of the SM-2s expended were launched from the two CMXs, except for CMX v3 case, in which the two CMXs ran out of missiles. The following table summarizes the missile inventories following the same attack sequence previously described;

Battlegroup Composition	Total Long Range Missiles Remaining	Long Range Missiles Remaining On CG and DDG	Long Range Missiles Remaining On CMX
1 CVN, 1 CG, 2 DDG 51, 2 CMX v3	0	0	-42
1 CVN, 1 CG, 2 DDG 51, 2 CMX v4	62	40	20
1 CVN, 1 CG, 2 DDG 51, 2 CMX v5	124	40	82
1 CVN, 1 CG, 2 DDG 51, 2 CMX v6	184	42	142
1 CVN, 1 CG, 2 DDG 51, 2 CMX v7	244	42	202
1 CVN, 1 CG, 2 DDG 51, 2 CMX v8	306	42	264

These results showed that the number of missiles remaining on the CG and DDGs became almost constant. This indicated a need for a higher proportion of the total missiles assigned to originate from the CMX. It was initially assumed that twenty-five percent of the missiles assigned

would originate from the CMX, however, this greatly reduced the missiles remaining in the more capable combatants.

Further studies were conducted for the case in which the CMX carried sixty percent of the missile assignments, however this would require a higher firing rate from the CMX. The assumption was then made that it would be possible to build a missile that would have the capability (engagement range and speed) to be employed in this fashion. The results of this study are provided in the following table;

Table 2-6. Blue Water Engagement Scenario

Battlegroup Composition	Total Long Range Missiles Remaining	Long Range Missiles Remaining on CG and DDG	Long Range Missiles Remaining On CMX
1 CVN, 1 CG, 2 DDG 51, 2 CMX v3	0	0	-80
1 CVN, 1 CG, 2 DDG 51, 2 CMX v4	62	62	-18
1 CVN, 1 CG, 2 DDG 51, 2 CMX v5	124	70	50
1 CVN, 1 CG, 2 DDG 51, 2 CMX v6	184	80	104
1 CVN, 1 CG, 2 DDG 51, 2 CMX v7	244	80	164
1 CVN, 1 CG, 2 DDG 51, 2 CMX v8	306	80	226

As shown, the revised missile assignment rate results in a more rational missile distribution following the engagement.

The following conclusions were drawn from the above analysis:

- The task force with an additional CMX had significant missiles remaining onboard the major combatants, at the end of the engagement;
- When the engagement was not illuminator (saturation) limited, the task force could function adequately with two CMX v5 (or larger) hulls replacing a CG or DDG;
- The AAW coverage remained satisfactory until the number of AEGIS platforms dropped below four, assuming no other mission requirements for those vessels;
- The saturation limited scenario did not improve with the replacement of an AEGIS platform by a CMX; the number of missiles that could be engaged simultaneously, was reduced;
- It would probably be desirable to have the CMX expend its missiles first, thus leaving the major combatants as fully loaded as possible;
- A CMX with only 3 or 4 VLS modules reduced the overall engagement capability of the BG with little incremental improvement in the major combatant missile inventory;
- The CMX would need to defend against approximately three leaker missiles during the saturation scenario.
- The numerical study did not evaluate the impact of the carrier air wing on AAW coverage. In fleet practice, some zones are assigned to air units and 360 degree coverage is not accomplished by the exclusive use of surface combatants.

4. Small Surface Action Group Engagement

The resurgent Russian Empire has extensive alliances with the Moslem world. After a blue water engagement such as that described in the previous section, some of these Moslem allies may be prompted to engage American forces in the Gulf of Sidra. This scenario postulated this type of reaction and provided an analysis of the effectiveness of the CMX as employed against a small surface action group.

a. Assumptions

The scenario was designed as follows. Two American warships were deployed in the Gulf of Sidra. Libyan forces consisted of several groups of small combatants. Nanuchkas and Combattantes have sailed from Tripoli and Benghazi, shore based Libyan assets have detected the American vessels. The primary US objective was to maintain the current patrol. The following forces have been mustered by Libya:

Platform	Number	ASUW Missile	Range (nm)	Number	Pk
Nanuchka II	5	Styx	43	4	0.65
Combattante IIG	4	Otomat MK1	32	4	0.75
Osa II	6	Styx	25	4	0.4

A US BG consisting of either two DDG 51s or an AEGIS platform and a CMX variant was been deployed. The number of Anti-Air Warfare (AAW) missiles for each platform was estimated. Each of the six CMX variants is described in the following table. An Evolved Sea Sparrow system was assumed to have been developed. This system will be discussed later in this

report. The parameters for missile ranges and probability of kill (Pk) were drawn from open sources. For this analysis, the naval combat simulator Harpoon™ was used to model the battlegroup response to the Libyan missile attacks on the combination of two DDG 51s. A synthetic CMX was modeled by using a superposition of a merchant ship and a DD 963 with its air search radar turned off.

Platform	ASUW Weapon	Range (nm)	Number	PK
Ticonderoga VLS	SM-2 Block II	50	74	0.8
	Evolved Sea Sparrow	10	32	0.75
DDG 51 IIA	SM-2 Block IV	60	54	0.8
	Evolved Sea Sparrow	10	32	0.75
CMX v3	SM-2 Block IV	60	73	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v4	SM-2 Block IV	60	104	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v5	SM-2 Block IV	60	133	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v6	SM-2 Block IV	60	165	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v7	SM-2 Block IV	60	195	0.8
	Evolved Sea Sparrow	10	72	0.75
CMX v8	SM-2 Block IV	60	226	0.8
	Evolved Sea Sparrow	10	72	0.75

b. Scenario

Two US vessels were on patrol off the coast of Libya. Following the destruction of the RRN battlegroup, attacks had been made against US forces around the world by Moslem fundamentalist groups. US forces were at a heightened state of readiness. The effectiveness of the battlegroup was analyzed with, and without the CMX. The Harpoon™ simulator was used to determine if the task group was missile, illuminator or hull limited. The CMX would be loaded with various numbers of SM-2 missiles.

Ship Combination	Tomahawk Cruise Missiles
DDG plus CMX v3	120
CG plus CMX v3	132
DDG plus CMX v4	150
CG plus CMX v4	162
DDG plus CMX v5	180
CG plus CMX v5	192
DDG plus CMX v6	211
CG plus CMX v6	223
DDG plus CMX v7	242
CG plus CMX v7	254
DDG plus CMX v8	272
CG plus CMX v8	284

c. Evaluation

While the scenario revealed the need to provide close escort, the use of the synthetic CMX was inconclusive. The model was not judged successful in simulating a CMX. The characteristics of the CMX do not approach the superpositioned ship. The program revealed that

for this stage of the analysis, there were too many variables to simulate. Three Sixty, Inc., the manufacturer of Harpoon™, has agreed to insert a CMX model into its database. As of the completion of this report, the new CMX model database was not yet available.

5. Summary

The scenario studies demonstrated the utility of a platform with a large missile inventory and a reduced combat system. The individual scenarios also served to highlight the capabilities provided by the proposed vessel and the limitations imposed on the battlegroup by the vessel. These are summarized as follows:

- The Land Strike, Amphibious Assault and Blue Water Engagement scenarios demonstrated that the employment of the CMX dramatically increased the sustainability of a battlegroup even when used as a replacement for a more expensive platform.
- The Land Strike and Amphibious Assault scenarios showed little degradation in battlegroup performance with the addition of the CMX.
- The Blue Water Engagement scenario resulted in significantly greater missile inventories remaining in the major combatants when at least 6 VLS modules with a longer legged missile are provided to the battlegroup via the CMX.
- Some of the capability of the battlegroup was degraded in the Blue Water Engagement scenario. There were fewer ASW capable platforms and the battlegroup became illuminator limited. This latter degradation was important when determining saturation.

- The Small Surface Action Engagement illustrated the need to provide close escort for the CMX. Without the escort, the self-defense capability of the CMX was overwhelmed by one or two fast patrol boats.

C. OPERATIONAL REQUIREMENTS DOCUMENT (ORD) FOR LARGE CAPACITY MISSILE CARRIER (CMX) 2010

1. General Description of Operational Capability.

The world view scenario provided by the Faculty Board required that the role of the Navy be redefined for the year 2010. The new Russian commonwealth, in consort with its Moslem allies, threatens resources vital to the US and its allies. However, the US Navy -- weakened from the military drawdown of the nineties -- is not capable of meeting all of the challenges implied by the threat. Specifically, the scenario presumes that one effect of the Russian-Moslem alliance is an increase in the number and intensity of regional conflicts. Although the US Navy possesses the ships required to support littoral warfare, these ships do not contain sufficient firepower -- namely, missiles -- to defend our regional interest for any protracted period of time. To achieve this ability the Navy must either modify existing ships to provide the magazine capacity to support sustained operations, or design a new ship to meet this need. The Faculty Board proposed that one possible solution would be to design a new ship, with the primary mission of bringing more missile to bear in any given conflict. This study examines the feasibility of designing such a "missile carrier."

The combat scenarios examined supported this effort to determine the mission need and to develop requirements for the vessel. In general, the results of this study indicated a ship capable of carrying several hundred missiles would be required.

2. Cooperative Engagement Capability (CEC)/Offboard Command Launch (OCL)

Two concepts concerning weapon systems employment, currently in development, are Cooperative Engagement Capability (CEC) and Offboard Command Launch (OCL).

a. Cooperative Engagement Capability (CEC)

The CEC concept, currently in development by Naval Space and Warfare Systems Command (SPAWAR), involves the tactical employment of AAW weapon systems on a force level. Its purpose is to overcome limitations of ability of individual platforms to engage due to enemy countermeasures and/or physical/environmental influences.

Force level employment would include all functional areas such as detection and tracking, threat assessment and target assignment, weapon selection, electronic warfare and EMCON, kill/damage assessment and graceful degradation and reconfiguration for battle damage.

The CEC concept is based on a real-time data base shared amongst all surface and air units within the battle force. This data base would provide initial offboard targeting and target updates and support a universal missile guidance mode for all platforms via multi-path communications relays.

All development efforts are currently being tailored to establish these system architecture goals by the year 2020.

b. Offboard Command Launch (OCL)

The OCL concept would incorporate the same components of the Offboard Command Casualty Launch (OCCL) concept, however it would be employed as a normal vice damaged operating mode. The OCCL concept, currently in development by Naval Sea Systems Command (NAVSEA), involves the control of a (damaged) unit's AAW weapon system (VLS) by another unit's fire control system.

Employment of the OCCL concept would involve the two ships establishing a communications link. The control ship would then initialize and issue configuration orders to the VLS on the damaged ship, and initiate the SM-2 launching sequence. After launch, the control ship would acquire the missile and provide illumination through the missile's terminal phase.

The OCCL concept would provide for improved overall missile usage of the battle force and improved battle force tactical strategy. The AEGIS system can be configured to support OCCL with minor changes to the command and decision, ACDS and weapon control system computers, and further development of specific OCCL data link/control software.

It was assumed, by the Design Team that development of the OCL concept and support equipment would be complete by 2010, and would be available to incorporate into the CMX combat system.

3. Threat.

The threat faced in 2010 will be primarily from modern, capable weapon systems operated by Russian forces or their Moslem allies. We anticipate that the weapons encountered will be a mixture of US, Russian, French and Chinese built. Thus, the CMX must be employed against a range of threats including:

a. Air and surface launched anti-ship missiles with all categories of sophisticated homing techniques;

b. Surface and submarine launched torpedoes in shallow water engagements;

c. Waters infested with all varieties of mines;

d. Small and medium caliber gunfire from coastal patrol craft;

e. Biological and chemical agents;

f. Covert attack by special forces;

4. Shortcomings of Existing Systems.

Analysis of various scenarios likely to occur in the future world environment reveals that the forces available will not have sufficient missiles in the magazines at the point of engagement. One alternative is to provide more vessels to the Task Force Commander; however the reduced size of the future Navy will reduce the viability of this option. A second alternative is using aircraft to provide delivery vehicles, but this option requires ground bases and may be politically impossible or physically unavailable.

5. Range of Capabilities Desired.

Rough Order of Magnitude (ROM) studies were conducted to establish the parameters for the Range of Capabilities for the CMX (see Appendix C). The CMX would possess the following capabilities:

a. Transit all major commercial shipping canals and waterways;

b. Operate at a (sustained) speed of 28 knots for 72 hours;

c. Endurance: 8000 nautical miles at 20 knots;

d. Operate at highest readiness condition for two weeks at a time;

e. 100% operational capability in all oceans through sea state five;

f. Completely integrate the shipboard combat system including Cooperative Engagement Capability (CEC) and Offboard Command Launch (OCL).

g. Employ AAW, ASUW and STW weapon systems configured for OCL.

h. Employ ASUW and STW weapon systems independently.

i. Provide AAW and ASUW self-defense against limited duration attacks;

j. Provide ASUW and STW support of Amphibious Task Force (ATF);

k. Provide Theater Ballistic Missile Defense (TBMD);

l. Attack high value land based military targets (both coastal and interior);

m. Receive real time targeting information from diverse sources;

n. Employ torpedo countermeasures;

o. Operate in mine infested waters;

p. Possess rapidly configurable C^3 system for interoperability with joint or coalition forces;

q. Operate in chemical, biological and radiological environments;

r. Sustain a six month forward deployment schedule with a two week replenishment interval;

s. Remain operational for a projected lifetime of 50 years;

t. Display low radiation and signal signatures;

u. Satisfy naval shock qualification requirements;

v. Implement an intelligent damage control system;

w. Support an organic aviation asset;

x. Support flight operations of non-organic joint force helicopters;

y. Incorporate advanced survivability measures;

6. General Affordability Limits.

The average acquisition cost of the CMX should be less than 600 million 1992 dollars.

7. Integrated Logistics Support.

The CMX is expected to operate in conjunction with other US and allied forces. It would rarely operate independently. However, it is anticipated that the CMX would be used for long duration in the vicinity of expected trouble spots. Therefore, the following Integrated logistics Support (ILS) would be necessary:

a. Modular design of weapons, sensors, communications and propulsion equipment to facilitate upgrade and repair;

b. Arrangement of equipment and machinery to ease change out and repair of components and minimize interference removal;

c. Commonality of components, unless significant system performance degradation occurs;

d. Automated component monitoring including Built-In-Test-and-Evaluation (BITE) and Automated Test and Evaluation (ATE);

e. Manning not to exceed 200.

8. Infrastructure Support and Interoperability.

The CMX would have the following interoperability features:

a. The SM-2 missiles carried by the CMX would be capable of being targeted and controlled by other vessels with Offboard Command Launch capability;

b. CMX would be capable of receiving targeting data from joint/coalition forces;

c. CMX would have a 10 year overhaul cycle.

9. Force Structure.

There would be 30 CMXs constructed.

10. Other Considerations.

The Scenario Study indicated that employment of the CMX would be advantageous when an engagement arises requiring a significant number of missiles. Several current threats (Iraq, Serbia) may require engagement in the near future. The emergence of any hostile world power would also require the delivery of a large number of missiles during a conflict. Failure to provide this capability may result in loss of the forces committed to the conflict.

D. REQUIRED OPERATIONAL CAPABILITIES (ROC)

Based on the Range of Capabilities Desired section of the Requirements Document, the following Required Operational Capabilities (ROC) and design requirements are delineated;

1. Primary ROCs

a. Completely integrate the shipboard combat system including Cooperative Engagement Capability (CEC) and Offboard Command Launch (OCL);

b. Provide AAW self-defense against limited duration or low intensity attacks;

c. Deliver ASUW and STW support of Amphibious Task Force (ATF);

d. Provide Theater Ballistic Missile Defense (TBMD);

e. Attack high value land based military targets (both coastal and interior);

f. Receive real time targeting information from diverse sources;

g. Possess rapidly configurable C^3 system for interoperability with joint or coalition forces;

h. Employ torpedo countermeasures;

i. 100% operational capability in all oceans through sea state five;

2. Secondary ROCs

a. Operate in mine infested waters;

b. Operate in chemical, biological and radiological environments;

c. Support an organic helicopter;

d. Support flight operations of non-organic joint force helicopters;

3. Primary Design Requirements

a. Transit all major commercial shipping canals and waterways;

b. Operate at sustained speeds of 26 to 28 knots for 72 hours;

c. Endurance: 8000 nautical miles at 20 knots;

d. Operate at highest readiness condition for two weeks at a time;

e. Sustain a six month forward deployment schedule with a two week replenishment interval;

f. Implement an intelligent damage control system;

g. Incorporate advanced survivability measures;

4. Secondary Design Requirements

a. Remain operational for a projected lifetime of 40 years;

b. Display low radiation and signal signatures;

c. Satisfy naval shock qualification requirements;

d. Support flight operations of non-organic joint force helicopters;

The Primary ROCs applicable to the CMX parallel those for the DDG/CG as defined in OPNAVINST C3501.2H, Naval Warfare Mission Areas and Require Operational Capability/Projected Operational Environment (ROC/POE). The table, on the next page, lists these ROCs. ROCs associated with CEC or OCL mission requirements are denoted by **.

TABLE 2-1. PRIMARY REQUIRED OPERATIONAL CAPABILITIES (ROC)

Reference: OPNAVINST C3501.2H, Naval Warfare Mission Areas and Require Operational Capability/Projected Operational Environment (ROC/POE)

ANTI-AIR WARFARE (AAW). The destruction or neutralization of enemy air platforms and airborne weapons, whether launched from air, surface, subsurface or land platforms.

AAW 1 Provide anti-air defense in cooperation with other forces.**
- AAW 1.2 Provide self-defense.
- AAW 1.5 Support area defense for amphibious forces in transit and in Amphibious Objective Area (AOA).**
- AAW 1.6 Support area defense for a Surface Action Group (SAG).**

AAW 2 Provide anti-air defense of a geographic area (zone) in cooperation with other forces.**

AAW 3 Engage air targets in cooperation with other forces.**

AAW 6 Detect, identify and track air targets.
- AAW 6.1 See Reference.
- AAW 6.2 Recognize by sight, friendly/enemy A/C which may be encountered in extended operating area.
- AAW 6.3 Maintain accurate air plot.
- AAW 6.4 Measure A/C altitude by radar.
- AAW 6.5 Detect, identify and track air targets with radar.
- AAW 6.6 Acquire and track targets with Missile Fire Control System (MFCS).
- AAW 6.7 See Reference.
- AAW 6.8 See Reference.
- AAW 6.9 Conduct PRCA for embarked A/C under all weather conditions.
- AAW 6.10 See Reference.
- AAW 6.XX Detect and track air targets with infrared sensor.

AAW 9 Engage airborne threats using surface-to-air armament.**
- AAW 9.1 Engage high speed, med/long range airborne threats with med/long range missiles.**
- AAW 9.3 Engage low altitude threats with missiles and gunfire.**
- AAW 9.6 See Reference.**
- AAW 9.XX Launch surface-to-air armament in conjunction with Offboard Command Launch (OCL) concept.**

ANTI-SURFACE WARFARE (ASU). The destruction or neutralization of enemy surface combatants and merchant ships.

ASU 1 Engage surface threats with anti-surface weapons.**
- ASU 1.1 Engage surface ships with long range cruise missiles.**
- ASU 1.2 Engage surface ships with medium range cruise missiles.**
- ASU 1.XX Launch anti-surface armament in conjunction with Offboard Command Launch (OCL) concept.**

ASU 2 Engage surface targets during BG operations in cooperation with other forces.**
- ASU 2.1 Operate as a member of a multi-ship SAG.**
- ASU 2.2 Operate in direct support of surface forces.**
- ASU 2.4 Operate in coordination with land and sea based air forces in conducting long range surface actions.**

ASU 3 Support anti-surface ship defense of a geographical area (e.g. zone or barrier) in cooperation with other forces.**

ASU 4 Detect, identify, localize and track surface targets.
- ASU 4.1 Detect, identify, localize and track surface targets with radar.
- ASU 4.4 Detect and track surface contacts visually.
- ASU 4.5 Detect, identify, localize and track surface targets with infrared.
- ASU 4.6 Detect, identify, localize and track surface targets by ESM.
- ASU 4.7 Identify surface contacts.
- ASU 4.11 Prosecute attack using Link 4A targeting information.**

ASU 6 Disengage, evade and avoid surface attack.**
- ASU 6.1 Employ countermeasures.**
- ASU 6.2 Employ evasion techniques.
- ASU 6.3 Employ EMCON procedures.
- ASU 6.4 Detect, identify and track targets to perform contact avoidance using ESM or RDF.

ASU 8 Provide for air operations in support of anti-surface attack operations.
- ASU 8.1 Launch rotary wing aircraft in support of anti-surface operations.
- ASU 8.2 Recover rotary wing aircraft in support of anti-surface operations.

ASU 12 Support and conduct independent ASU operations.
- ASU 12.2 Conduct ASU operations while escorting ATF or protecting an AOA.**
- ASU 12.3 Conduct ASU self-defense operations.

ASU 13 Conduct pre-attack deception operations.

ANTI-SUBMARINE WARFARE (ASW). The destruction or Neutralization of enemy submarines.

ASW 8 Disengage, evade, avoid and deceive submarines.
- ASW 8.1 Employ torpedo countermeasures and evasion techniques.

COMMAND, CONTROL AND COMMUNICATIONS (CCC). Providing communications and related facilities for coordination and control of external organizations or forces and control of unit's own facilities.

CCC 3 Provide own units C^3 functions.

CCC 3.1 Maintain a CIC capable of collecting, processing, displaying, evaluating, and disseminating tactical information.
CCC 3.3 Provide all necessary personnel services, programs, and facilities to safeguard classified material and information.
CCC 3.4 Carry out emergency destruction of classified matter and equipment rapidly and efficiently.
CCC 3.5 Employ Identification Friend or Foe/Selective Identification Feature (IFF/SIF) secure IFF mode 4.
CCC 3.6 Coordinate and control the operation of remotely piloted vehicles.
CCC 3.8 Establish voice communications with US. Marine Corps (USMC) evacuation and command nets and Naval Support Activity (NSA) net.

CCC 4 Maintain NTDS data link capability.**

CCC 4.3 Transmit/receive and support Link 11.**
CCC 4.5 Receive and process data link information from Satellite Communication (SATCOM).**
CCC 4.6 Receive and process data link information from High Frequency (HF) systems.**
CCC 4.7 Receive Link 14 information.**
CCC 4.9 Transmit/receive and support Link 16 (JTIDS) surveillance, navigation and identification circuits.**
CCC 4.10 Transmit/receive and correlate targeting information with Link 4A.**

CCC 6 Provide communications for own unit.

CCC 6.1 Provide tactical voice communications.
CCC 6.2 Provide visual communications.
CCC 6.3 Provide multi-channel cryptographically covered teletype send and receive circuits.
CCC 6.4 Provide uncovered Radio-Teletype/Continuous Wave communications.
CCC 6.5 Provide full duplex cryptographically covered HF teletype circuits.
CCC 6.10 Provide voice/teletype/computer data cryptographically covered satellite communication circuits.
CCC 6.11 Establish and provide fixed combat communications and relay support for NSW operations.
CCC 6.12 Provide internal communications systems.
CCC 6.16 Provide tactical, secure, anti-jam Ultra-High Frequency (UHF) voice communications.
CCC 6.18 Provide tactical, secure, anti-jam HF voice communications.
CCC 6.19 Provide tactical, secure voice or data communications.

CCC 9 Relay Naval communications with visual and electronic means.

CCC 9.1 Relay visual communications.
CCC 9.3 Relay electronic communications.

ELECTRONIC WARFARE (ELW). The effective use by friendly forces of the electromagnetic spectrum for detection and targeting while deterring, exploiting, reducing or denying its use by the enemy.

ELW 1 See Reference.**

ELW 1.1 See Reference.
ELW 1.2 See Reference.
ELW 1.3 See Reference.
ELW 1.5 See Reference.**

ELW 2 See Reference.

ELW 2.2 See Reference.
ELW 2.5 See Reference.
ELW 2.6 See Reference.
ELW 2.7 See Reference.
ELW 2.10 See Reference.

ELW 3 See Reference.**

ELW 3.1 See Reference.**
ELW 3.2 See Reference.**

ELW 4 See Reference.

ELW 4.1 See Reference.
ELW 4.2 See Reference.
ELW 4.3 See Reference.

ELW 5 See Reference.**

MOBILITY (MOB). The ability of naval forces to move and to maintain themselves in all situations over, under or upon the surface.

MOB 1 Steam to designed capability and in most fuel efficient manner.

MOB 1.1 Steam at full power.
MOB 1.2 Steam with split plant.
MOB 1.5 Steam at sustained BG/SAG speeds.
MOB 1.6 Maintain necessary machinery redundancy to enhance survival in high threat areas.
MOB 1.7 Transit at high speed.

MOB 3 Prevent and control damage.

MOB 3.1 Control fire, flooding, electrical, structural, propulsion and hull casualties.
MOB 3.2 Counter and control CBR contamination/agents.
MOB 3.3 Maintain security against unfriendly acts.
MOB 3.5 Provide DC security and surveillance.
MOB 3.8 Provide EBDs in accordance with ships allowance.

MOB 5 Maneuver in formation.

MOB 7 Perform seamanship, airmanship and navigation tasks.

MOB 7.1 Navigate under all conditions of geographic location, weather, and visibility.

MOB 7.2 Conduct precision anchoring
MOB 7.3 Get underway, moor, anchor, and sortie with duty section in a safe manner
MOB 7.5 Utilize programmed evasive steering.
MOB 7.6 Abandon/scuttle ship rapidly
MOB 7.7 Provide life boat/raft capacity IAW ships allowance
MOB 7.8 Tow or be towed.
MOB 7.9 Operate day and night and under all weather conditions.
MOB 7.14 Moor alongside ATF shipping or docks.
MOB 7.15 Operate in a chemically contaminated environment

MOB 10 Replenish at sea.
MOB 10.1 Receive VERTREP.
MOB 10.2 Receive fuel while underway (alongside method).
MOB 10.3 Receive munitions and provisions while underway.
MOB 10.4 Receive potable and/or feed water while underway.

MOB 12 Maintain the health and well-being of the crew.
MOB 12.1 Ensure all phases of food service operations are conducted consistent with approved sanitary procedures and standards.
MOB 12.2 Ensure the operation of the potable water system in a manner consistent with approved sanitary procedures and standards.
MOB 12.3 Maintain the environment to ensure the protection of personnel from overexposure to hazardous levels of radiation, temperature, noise, vibration, and toxic substances per current instructions.
MOB 12.5 Monitor to ensure that habitability is consistent with approved habitability procedures and standards.
MOB 12.6 Ensure operation and maintenance of all phases of shipboard environmental protection systems do not create a health hazard and are consistent with other naval directives pertaining to the prevention of pollution of the environment.

STRIKE WARFARE (STW). Support the destruction or neutralization of enemy targets ashore through the use of conventional weapons.

STW 3 Support/conduct multiple cruise missile strikes either independently or in support of other strike forces.**
STW 3.2 Support/conduct conventionally armed cruise missile strikes.**
STW 3.3 Provide navigation/targeting data to missile fire control and guidance subsystems with specified accuracy.**
STW 9.XX Launch cruise missile strike in conjunction with Offboard Command Launch (OCL) concept.**

STW 8 Provide for air operations in support of air strike operations.**
STW 8.1 Launch fixed and/or rotary winged aircraft involved in air strike operations.**
STW 8.2 Recover fixed and/or rotary winged aircraft involved in air strike operations.**

III. DESIGN PHILOSOPHY

A statement of priorities was established from which the design team would base trade-off decisions. These priorities were established to ensure that the trade-offs would be made in a consistent manner. This chapter outlines and justifies the priorities which formed the Design Philosophy for the CMX.

A. PRIORITY OF DESIGN CONSIDERATIONS

To develop this list of priorities, the Design Team evaluated many facets of naval ship design, including military and technical considerations. Political and social issues were also evaluated. Using the Requirements Document (see Chapter II, Section C) as a guide, the Team developed list of the highest priority design considerations as follows:

- Cost
- Combat System Effectiveness (CEC/OCL)
- Combat System Effectiveness (self-defense)
- Survivability/Vulnerability
- Manning Reduction

Note that this list is not ordered. The Team felt that these considerations were of relatively equal or comparable priority level. Similarly, the Team established a list of design priorities to be considered next:

- R, M and A
- Future Growth/Upgrade
- Standardization

- Commercial Off the Shelf (COTS)
- Detection Signature
- Environmental Impact

The following design priorities were also considered (lowest priority):

- Specifications
- Appearance
- Habitability
- Political/Societal Issues

B. JUSTIFICATION

1. High Priorities

a. *Cost*

Cost was given a high priority due to the TOR specifying low cost as a design objective. The ORD was written limiting the ship cost to 600 million 1992 dollars. This cost was to be significantly less than the cost of an AEGIS ship. Failure to meet this objective would most likely kill this program at the DOD and Congressional levels of review.

b. *Combat System Effectiveness (CEC/OCL)*

Combat effectiveness in the CEC/OCL role was given high priority since it is the primary mission requirement for the ship. The Scenario Studies justified the existence of the CMX based on its capabilities in this role, and it must be viewed as a primary design consideration.

c. Combat System Effectiveness (Self-Defense)

Although the CMX would be escorted into any high threat area, its function of enhancing the capabilities of the battlegroup in a hostile engagement make it a likely target. The inability to defend itself would have a significant negative impact on the outcome of an engagement. For these reasons, self-defense was given a high priority.

d. Survivability/Vulnerability

Poor survivability and high vulnerability would have the same impact as poor self-defense capability, and as such, were also given high priority.

e. Manning Reduction

Having a significant impact on overall ship cost, manning reduction was given high priority. The level of automation of ship, weapon systems and engineering plant controls, directly affects the degree of manning reduction achievable. Additionally, maintenance and damage control manning requirements must be considered.

2. "Next" Priorities

a. R, M And A

While not ranked as high as primary mission or manning considerations, R, M and A was still viewed as an important priority due to second order effects on manning requirements and overall mission capability for the ship.

b. Future Growth/Upgrade

Future growth and upgradability was considered important since the CMX must be reasonably adaptable to advances made in weapon technology.

c. Standardization

Standardization was considered to support future growth and upgradability provided there would be no negative impacts on cost, manning or R, M, and A considerations.

d. Commercial Off The Shelf (COTS)

COTS considerations were viewed to parallel standardization.

e. Detection Signature

Improvements in detection signature was considered due to its impact on the ship's primary mission capabilities and vulnerability.

f. Environmental Impact

Environmental impact considerations were made in order to meet regulatory requirements.

3. "Also" Priorities

a. Specifications

Specifications (i.e., weights, volumes, power requirements) were considered in order to avoid negative impact on higher priorities such as primary mission or manning requirements.

b. Habitability

Habitability was considered so as not to conflict with higher priority considerations such as reduced manning, R, M and A, vulnerability, primary mission or cost requirements. Sufficient habitability standards would be considered so as to provide adequate living space for all crew members without compromising morale.

c. Political/Societal Issues

Political and societal issues address those design considerations currently used in naval ship design due to tradition, standard practice or "because it's always been done that way." The Team decided that such issues would not influence the design considerations for this ship.

d. Appearance

Although there were no requirements for the CMX to play a role in power projection or to "show the flag", it would frequently be in the company of ships that had such requirements, especially when escorted into a high threat area. Therefore, design attributes affecting the appearance of the CMX would be considered, provided no negative impact would result for higher design priorities.

IV. COMBAT SYSTEM DEFINITION

In this phase of the design process the elements that would comprise the combat system of the CMX were selected. The categories of elements considered included detection, engagement, and communication, computers and control elements. The detection element category was further subdivided into surface search/navigation radar, air search/tracking radar, aviation/navigation support, and electronic warfare elements. The selection methodology was based on a determination of what prospective combat system capabilities would be effectively employed against a spectrum of threats which resulted from the operational scenarios presented in Chapter II.

The approach to the combat system definition began with the application of the Operational Requirements Document (ORD) and the Ship Design Philosophy (presented in chapters II and III, respectively), in the form of priorities, to the combat system. These priorities were used as a basis for the tradeoff analysis and element selection.

The effectiveness of the selected elements was then evaluated against various threats, and the performance of the combat system was analyzed using the operational engagements developed as a result of the Scenario Study.

Section A of this chapter presents an overview of the design philosophy as it was applied to the combat system. Section B discusses the tradeoff methodology and element selection. The evaluation of the proposed CMX Combat System is included in Section C. Section D summarizes the combat system definition for the CMX.

A. COMBAT SYSTEM DESIGN PHILOSOPHY

Based on the ORD and the Ship Design Philosophy, the following discussion further develops the high priority ship design considerations as applicable to the CMX combat system.

The primary mission for the CMX combat system would be to support the Offboard Command Launch (OCL) and the Cooperative Engagement Capability (CEC) operational concepts. The CMX would carry the most potent offensive and defensive vertically launched missiles of the U.S. Fleet: SM-2 AAW missiles and Tomahawk land attack cruise missiles. These missiles would be fired under the remote or off-board control of accompanying AEGIS cruisers or guided missile destroyers. Thus, a major focus of the CMX combat system would be to guarantee the most effective data communication and control systems necessary for the remote ship engagement capability. The local self-defense capability must also be highly effective in order to safeguard the offensive strike and defensive AAW payload which the CMX would contain.

An accompanying AEGIS ship would provide long range sensor service and would control defensive engagements beyond the self-defense range of the CMX. The CMX local combat system would be designed to handle "leakers" from larger battle group defensive actions. For this reason, the CMX sensors need to possess only short range.capability. The CMX self-defense system must integrate remote data link target tracks with local sensors, identify tracks within a self-defense zone, and successfully defend itself. The CMX must also have local ASUW capability to fend off surface threats in littoral waters so as not to unnecessarily burden the AEGIS platform.

The CMX system must be survivable and affordable. To this end, automatic close-in reaction and engagement would be necessary to ensure that combat system defensive manning would be minimized. Simplicity, reliability, and effectiveness were also underlying qualitative factors which describe the CMX combat system requirements.

In addition to the above, was the requirement to minimize overall ship cost and manning. System automation achieved through technical advances and system integration must be high design priorities.

This discussion provided the basis for the tradeoff methodology used in the element selection process.

B. TRADEOFF METHODOLOGY AND ELEMENT SELECTION

Tradeoff studies were conducted by the design team using both analytical and qualitative methods. The design philosophy (described in the previous section) provided the structure for the tradeoff studies and final element selection. The analytical tradeoff methodology involved assigning weighting factors to the ship design philosophy priorities (by group) to reflect their relative importance. The ship design philosophy priority groups and the assigned weighting factors are provided in the following table:

Ship Design Priority Group	Weighting Factor
High Cost Combat System Effectiveness (CEC/OCL) Combat System Effectiveness (self-defense) Survivability/Vulnerability Manning Reduction	1
"Next" R, M and A Future Growth/Upgrade Standardization Commercial Off the Shelf (COTS) Detection Signature Environmental Impact	0.4
"Also" Specifications Appearance Habitability Political/Societal Issues	0.2

Data on both current and future elements considered for the combat system elements was obtained from open sources (see References). The elements considered for each subsystem of the combat system were then assigned a rating index (1, 2 or 3, 1 being the most desirable) to reflect their relative performance (or value) with respect to each ship design priority. These indices were assigned based on the open source data when available, otherwise, the engineering judgment and past experience of the Design Team were employed. In some cases, no index was assigned, indicating no significant contribution to a particular design priority. Weighted sums of the rating indices were then calculated to determine an overall ranking of the element. The elements receiving the lowest numerical ranking were initially considered the most suitable for the combat system.

A qualitative check of the analytical results was conducted for each element achieving the highest ranking prior to final selection. This check synthesized the analytical results with engineering judgment to provided a sense of logic and integrity to the selection process.

In the following sections, a list of the elements considered is provided for each functional area of the combat system. The tradeoff decision matrices with analytical results are included, followed by a qualitative discussion of the results and the most notable factors driving each selection. Comparison of performance features or specific data are made as a direct result of information obtained in the open literature (see References). Tables of performance parameters for the elements selected are also provided.

1. Detection Elements

a. Surface Search/Navigation Elements

(1) Elements Considered

The following surface search, tracking, and navigation radars were considered as candidates for use in the CMX combat system:

(a) AN/SPS-67

(b) AN/SPS-64

(c) AN/SPS-55

(d) AN/SPQ-9(i)

(e) AN/SPS-58 & AN/SPS-65(V)

(f) Furuno Radars (various)

The following non-radar type sensors were also considered:

(g) Radiant Mist

(2) Discussion of Tradeoffs

Detailed design priority ratings for surface search/navigation elements are included in the table on the following page.

Surface search and navigation radars can be broadly categorized as Class A, B1 and B2 where Class A indicates full military specification and high cost, Class B1 indicates partial military specification and moderate cost, and Class B2 indicates commercial-off-the-shelf (COTS) technology at a generally low cost. Class A surface radars include the AN/SPS-55,

Table 4-1. Surface Search/Navigation Element Selection

DESIGN PRIORITY	Weight Factor	ELEMENT						
		AN/SPS-55	AN/SPS-65	AN/SPS-67	AN/SPS-64	AN/SPQ-9(I)	RAD MIST	FURUNO
Cost	1	2	2	2	1	3	2	1
CEC/OCL Effectiveness	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Self-Defense Effectiveness	1	3	2	2	2	1	2	3
Survivability/Vulnerability	1	2	2	2	3	2	1	3
Manning Reduction	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
R, M and A	0.4	2	3	2	2	2	2	3
Future Growth/Upgrade	0.4	2	3	3	1	2	1	1
Standardization	0.4	3	3	1	1	1	3	2
Commercial Off the Shelf (COTS)	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Detection Signature	0.4	3	3	3	2	3	1	2
Environmental Impact	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Specifications	0.2	2	2	2	2	3	2	1
Appearance	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Habitability	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Political/Societal Issues	0.2	1	2	1	1	1	3	2
Weighted total		11.6	11.6	10.2	9	10	8.8	10.8

AN/SPS-67 and AN/SPQ-9(i). Although not a conventional detection element, Radiant Mist is being developed along the lines of a Class A system. Extremely high cost was a key factor in eliminating the AN/SPQ-9(i). The AN/SPS-55 scored relatively high but did not measure up to the CMX priorities. The AN/SPS-67, the current surface combatant surface radar mainstay, did not contribute to the goal of signature reduction.

The primary Class B1 surface radar is the AN/SPS-64. Class B2 radars include the RAYCAS system, various Furuno radars, and the LN-66.

Redundancy of surface search and detection elements is important for both safety of navigation and for combat system survivability standpoints. The Design Team selected one detection element from each category (A, B1/2) in order to achieve redundancy at relatively low cost. Radiant Mist, the Class A system choice, also supports the goal of detection signature reduction due to its passive search mode. Radiant Mist promises reduced operational and maintenance manning. All surface detection systems would be interfaced with the self-defense fire control and engagement systems to improve probability of detection and engagement of low flyers.

(3) Surface Search/Navigation Elements Selected

The AN/SPS-64 and Radiant Mist radars was selected to provide the primary surface search and navigation detection elements for the CMX.

The AN/SPS-64, is a Class B1 navigational and surface search radar with detection range capability up to 60 nautical miles. Originally manufactured by Raytheon in the late 1970's, this

radar will be upgraded and modernized under a new competitively bid contract during the 1990's. The resulting AN/SPS-64 system will be integrated with the commercial Raytheon Computer Aided Shipping System (RAYCAS) to automate surface tracking and plotting functions. This system could also be interfaced to provide initial detection information on sea-skimming ASCMs to the Mk 91 Sea Sparrow fire control system (FCS).

Radiant Mist, a new shipboard electro-optical sensor system that incorporates infrared (IR) imaging and laser radar, would complement the AN/SPS 64 while providing surface search and tracking capability. Radiant Mist has a programmed passive IR search mode which can be used for target detection. Low flyers or surface targets can be passively tracked and identified by the CO_2 laser in the Radiant Mist system. The system's laser radar can "interrogate" a target to perform independent automatic target recognition. In summary, Radiant Mist can detect, track, perform fire-control functions and positively identify air and surface targets. The system would be fully integrated with other ship sensors and fire control systems.

A summary of the characteristics the surface detection elements selected is provided in the following table:

Surface Detection Sensors Characteristics		
Parameter	**AN/SPS-64**	**Radiant Mist**
Range (nm)	60	horizon
Frequency/Band	I/J	IR/laser
Scan Rate	33	N/A
Antenna Size	8 feet	1 x 2 x 2 feet
Antenna Weight	132 lbs	200 lbs (est)
Console/Cabinet Weight	332 lbs	400 lbs (est)
Console/Cabinet Volume	25 ft^3	20 ft^3
Average Electric Power	0.4 kw	unknown
Cost	$40 K	$2 M

b. Air Search/Tracking Elements

(1) Air Search/Tracking Elements Considered

Both 2-D and 3-D air search and tracking radar systems were considered for the CMX combat system. Specific systems evaluated are the following:

(a) AN/SPS-48(E)

(b) AN/SPS-49

(c) MK 23 Target Acquisition System

(2) Discussion of Tradeoffs

Detailed design priority ratings are shown in the table on the following page.

Self-defense combat system effectiveness was the primary focus for air search radar selection. The AEGIS equipped command ship is expected to cover the defense area outside

Table 4-2. Air Detection Element Selection

DESIGN PRIORITY	Weight Factor	ELEMENT AN/SPS-48	AN/SPS-49	MK 23 TAS
Cost	1	3	2	2
CEC/OCL Effectiveness	1	1	2	2
Self-Defense Effectiveness	1	2	2	1
Survivability/Vulnerability	1	1	2	1
Manning Reduction	1	2	2	1
R, M and A	0.4	2	2	2
Future Growth/Upgrade	0.4	3	2	2
Standardization	0.4	2	2	2
Commercial Off the Shelf (COTS)	0.4	N/A	N/A	N/A
Detection Signature	0.4	3	3	1
Environmental Impact	0.2	N/A	N/A	N/A
Specifications	0.2	2	2	2
Appearance	0.2	N/A	N/A	N/A
Habitability	0.2	N/A	N/A	N/A
Political/Societal Issues	0.2	N/A	N/A	N/A
Weighted total		13.4	14	10.2

approximately ten nautical miles. And, the CMX concept itself is based upon the cost savings realized by the elimination of one SPY-1 radar system from the command ship and CMX combination. Thus, while the SPY-1 is the premier air search and tracking radar, it was not even considered as a candidate for the CMX. The self-defense and cost priorities also eliminated longer range, powerful air search radars such as the AN/SPS-48 and the AN/SPS-49.

Except when under attack or during times when attack may be imminent, it is expected that the CMX would operate in an EMCON condition where its sensors would be operated only in passive modes (e.g., Radiant Mist and SLQ-32). Data links from the AEGIS command ship would provide the surface and air plots. (Active surface search via the AN/SPS-64 and RAYCAS would be used during special circumstances such as entering or leaving port, transiting shipping lanes, and as required by International Rules of the Road). However, when attack is imminent, the ACDS data link tracks would be handed off to the local air search and track radar of the CMX. Thus, the MK 23 Target Acquisition System with its automatic tracking capability and its relatively short range was the element of choice for air search and tracking. Further, its capability against low flying ASCM targets is well established by current fleet exercise results.

(3) Air Search/Tracking Elements Selected

The Mk 23 Target Acquisition System (TAS) would handle the air search and tracking functions. The Mk 23 TAS can operate in four modes:

- Medium Range mode for surveillance and aircraft control out to 100 nautical miles;
- Point Defense mode to track and engage air targets within 20 nautical miles;

- Mixed mode which combines the above modes
- Emission Control (EMCON) mode where only selected sectors are scanned as desired by the operator.

The Mk 23 TAS can track up to 54 targets and provide targeting information for small AAW missiles such as Sea Sparrow or RAM. The TAS system is also compatible with standard fire control computers, Mk 12 IFF, AN/SLQ-32, vertically launched Sea Sparrow, SAR-8, Radiant Mist and RAM systems. The following table summarizes the MK 23 TAS characteristics:

MK 23 TAS Characteristics	
Range	100 nm
Power	200 kw (peak)
Frequency	1 - 2 GHz
Scan rate	19.1 rpm
Coverage	360° azimuth, 0 to 75° elevation
Antenna Dimensions	10.7 x 26.7 x 6.3 ft
Antenna Weight	2000 lb
System Weight	9000 lb
Average Electric Power	58 kw
Cost	$ 3.0 M

c. Aviation/Navigation Support Elements

(1) Aviation/Navigation Support Elements Considered

(a) Raytheon Collision Avoidance System V (RAYCAS V)

(b) TACAN (Replacement System)

(c) AN/WRN-6(V)1 Global Positioning System (GPS)

(d) AN/SRN-25 Omega C+F

(e) AN/WSN-5 Inertial Navigation System (INS)

(f) AN/WQN-1(V) Fathometer/Sonar

(2) Discussion of Tradeoffs

A tradeoff table scoring all feasible candidate elements against the design priorities would normally be evaluated prior to element selection. However, a detailed analytical tradeoff study was beyond the scope of this design project. The following discussion is included to support the considerations of the Design Team.

With the exception of RAYCAS, all aviation/navigation elements listed above represent the most modern variant of element type which are standard in the Fleet. The RAYCAS system would allow for reduced manning during special evolutions such as entering or leaving port, and transiting of high traffic shipping lanes. The Tactical Air Navigation (TACAN) Replacement System was selected as standard equipment onboard DDG-51 and future US surface combatant ships. GPS would provide the primary navigation information and would also be used as an update reference for the AN/WSN-5. The AN/WSN-5 would provide the stabilization data necessary for the fire control systems. Omega would provide a backup system for navigation.

The fathometer is standard equipment on ships without an ASW sonar system, and the AN/WQN-1(V) is considered the most modern fathometer element.

(3) Aviation/Navigation Support Elements Selected

Considering relatively unique functional characteristics and standard use aboard US naval surface combatants, the newest variants of the equipment discussed above will be installed onboard the CMX.

d. Electronic Warfare Elements

(1) Electronic Warfare Elements Considered

(a) SLQ-32(V2) ESM

(b) SLQ-32(V3) ESM/ECM

(c) WLR-1(H)

(2) Discussion of Tradeoffs

A tradeoff table scoring all feasible candidate elements against the design priorities would normally be evaluated prior to element selection. However, a detailed analytical tradeoff study was beyond the scope of this design project. The following discussion is included to support the considerations of the Design Team.

Although highly rated by the Fleet, the AN/WLR-1H was rejected for the CMX primarily due to its requirement for an operator to manually scan the radio/radar spectrum. SLQ-32(V2) lacked the self-defense effectiveness required for the CMX. SLQ-32(V3) was specifically selected due to its active jamming capability.

(3) Electronic Warfare Elements Selected

The AN/SLQ-32(3) was selected as the electronic support (ESM) and countermeasures system (ECM). This computerized system employs an internal library of transmission characteristics which it compares with detected signals in order to automatically categorize threats. Defensive reactions such as chaff, Torch and electronic jamming can be automatically triggered in the highest alert mode of operation. The system is fully integrated with the Advanced Combat Direction System (ACDS) and could direct ESM input to alert other fire control systems.

2. Command, Control and Communications (C^3) Elements

(1) C^3 Elements Selection

A tradeoff table scoring all feasible candidate elements against the design priorities would normally be evaluated prior to element selection. However, a detailed analytical tradeoff study was beyond the scope of this design project. The following discussion is included to support the considerations of the Design Team.

The Command, Control and Communications (C^3) suite must be capable of supporting both the Offboard Command Launch (OCL) of the SM-2 missiles in the vertical launchers and the self-defense combat system of the CMX. Thus, the CMX C^3 suite would incorporate some components of the Offboard Casualty Control Launch (OCCL) system (currently under feasibility study) and the future Advanced Combat Direction System (ACDS). Although a fully capable ACDS system greatly exceeds the requirements of the CMX, partial implementation of this system would be required in order to implement the future high speed data links and computer power

required for both the OCL and self-defense of the CMX. The following elements and systems would comprise the C^3 suite:

(a) ACDS

This system is the successor to the current Navy Tactical Data System (NTDS). ACDS would initially utilize several UYK 43 computers, and transition to even more powerful and state-of-the-art computers is expected for implementation in the CMX. ACDS would possess the data storage, computational, and display graphics capability to handle the increased surveillance volume of the accompanying AEGIS ship. ACDS would incorporate Link 11 Model 5 (LEMF) and the new Link 16 which has outstanding data security and data transfer rate. This system would allow local commanders to program an expert system's rule-database, for rapid auto-engagement of threats in accordance with current local tactical conditions. Finally, the system would be built with specific attention to reduced manning for both operation and maintenance.

(b) Link 16

Link 16 would connect the Navy to the Joint Tactical Information System (JTIDS). This system would handle extremely high data transfer rates with high security. This system would be the primary joint data net of the future.

(c) Link 11 Model 5

The next generation Link 11, Link Eleven, Model Five (LEMF), would possess greater data handling capability with higher security as compared to the current tactical data link.

(d) OTCIXS (AN/USQ-64(V)7)

The Officer-In-Tactical-Command Information Exchange System is the battle group's local command-and-control communication net. Current systems have low data transfer rates, typically on the order of 2400 baud. Future variants promise significantly improved data throughput.

(e) TADIXS A and B (AN/USQ-64(V)8 and AN/USQ-101)

The Tactical Digital Information Exchange System is a one-way broadcast from satellites to fleet units. It provides ocean surveillance data to the fleet units.

(f) CUDIXS

The Common User Digital Information System would carry two-way general service messages.

(g) OCL System 1

OCL System 1, as postulated by the Design Team, would provide necessary hardware and software to accomplish the offboard launch of the CMX's SM-2, Tomahawk or Harpoon missiles. This system would include the high speed data link, computer systems, multiplexed fiber-optic data bus, interface hardware CMX navigation/position sensors, and VLS control hardware.

(h) IVCS

A fiber optic Interior Virtual Communications System would provide own ship integrated interior communications. The system would be multiplexed to handle nearly infinite information.

These relatively light weight fiber-optic cables would be redundantly routed throughout the ship to improve survivability.

Other elements which support the above selections include

- AN/UYK-43 Computers (Next Generation)
- AN/USQ-119A(V) 10B Tactical Graphics System
- NAVMACS II
- AN/UGC-143A(V) NST
- OK-455(V) UHF DAMA
- AN/UYQ-62 C2P VER 1 Link Processor
- AN/WSC-3(V)3 UHF SAT Transmitter/Receiver
- AN/USC-38 EHF SATCOM
- TSECK/KWR-46 Crypto Equipment
- TSECK/KG-84A SATCOM Crypto
- TSECK/KG-84C Crypto Equipment
- AN/USC-43 ANDVT TACTERM
- AN/USC-43 ANDVT SATCOM
- R-2368A LF/MF/HF Receiver
- HF Broad Band
- VHF (30-88) VRC-46 RPL
- VHF (115-156) Upgrade
- UHF Basic Radios
- UHF AJ HAVE QUICK

3. CEC/OCL Weapons Systems/Engagement Elements

The following missiles would be installed onboard the CMX as dictated by the TOR and ORD.

a. Standard Missile SM-2

Improved SM-2 missiles launched from VLS would provide the offboard command launch (OCL) AAW and Theater Ballistic Missile Defense (TBMD). Block IV and future variants of these missiles would provide the main battery for fleet AAW defense for the next fifteen to twenty years. SM-2 missiles fired from the CMX would be controlled by an AEGIS equipped "command" ship.

b. Tomahawk

The Tomahawk Land-Attack Missile (TASM) will be the primary unmanned strike weapon for the U.S. Navy over the next twenty years. CMX would carry TASM as well as future variants of Tomahawk cruise missiles. The CMX would have the capability to initiate Tomahawk launches or to respond to a launch command via OCL System 1.

c. Harpoon (AGM/RGM/UGM-84)

Harpoon anti-ship cruise missiles would provide potent ASUW capability for the CMX and the OCL ship. Future Harpoon variants are expected to have increased range and improved flight profile characteristics. In addition, VLS launch capability is expected to be achievable by the year 2010.

4. Self-Defense Weapons Systems/Engagement Systems

a. Self-Defense AAW Elements

(1) Self-Defense AAW Elements Considered

(a) FIM-92 Stinger Missiles

(b) RAM

(c) Sea Sparrow

(d) MK 45 Lightweight 5" Gun

(e) MK 75 OTO Melara 76 mm Gun

(f) MK 38 Bushmaster 25 mm Gun

(g) MK 15 CIWS 20 mm Gun

(h) Goal Keeper

(2) Discussion of Tradeoffs

The table on the following page indicates the tradeoff analysis conducted for the selection of engagement elements. A brief discussion of the salient points of the selection process is included below. Other, soft-kill engagement decoy and deception elements have been included as standard equipment of modern US naval combatants.

CMX air defenses will be integrated with the defense in depth concept: the outer air battle will be conducted by tactical carrier aviation assets. The intermediate air defense will be primarily accomplished by AEGIS combatants with SM-2 missiles. Local ship defense would then require a moderate range AAW capable major caliber gun or a short range AAW missile, a last ditch Gatling gun system, and an integrated ECM/decoy system. Based on relatively

Table 4-3. Self-defense Weapon Systems/Engagement Elements Selection

DESIGN PRIORITY	Weight Factor	ELEMENT ESS	RAM	STINGER	5" GUN	76MM GUN	CIWS	GOALKEEPER	BUSHMASTER
Cost	1	2	2	1	3	3	2	2	1
CEC/OCL Effectiveness	1	2	1	1	3	3	N/A	N/A	N/A
Self-Defense Effectiveness	1	1	1	3	2	2	1	1	3
Survivability/Vulnerability	1	1	2	2	2	2	2	2	1
Manning Reduction	1	1	2	3	3	3	1	1	2
R, M and A	0.4	1	1	1	2	2	2	3	1
Future Growth/Upgrade	0.4	1	2	1	1	1	2	2	1
Standardization	0.4	1	1	1	1	1	1	2	1
Commercial Off the Shelf (COTS)	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Detection Signature	0.4	2	1	1	2	2	2	2	1
Environmental Impact	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Specifications	0.2	2	3	1	2	3	2	2	1
Appearance	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Habitability	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Political/Societal Issues	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Weighted total		9.4	10.6	11.8	15.8	16	9.2	10	8.8

low effectiveness and high ship cost, a major caliber gun system was rejected. While the Sea Sparrow systems have slight cost advantages over the RAM system and effectiveness data is relatively evenly matched, the future upgrade capability of the vertically launched Evolved Sea Sparrow (ESS) was a major factor favoring the its selection. The lower ship cost due to vertical launch installation, and the potential reliability and maintainability advantages from the VLS configuration further support the selection of ESS over RAM.

Self-defense AAW engagement elements are designed to eliminate threats which have leaked through each of the outer defensive layers. The lack of an established support base for the Goalkeeper gun was a marked disadvantage. Low cost and survivability were favorable factors contributing to the Bushmaster achieving the lowest ranking. The potential to upgrade the Vulcan Phalanx CIWS by re-gunning, in addition to its high effectiveness were considered to be significant factors and as such, the Team decided to overrule the decision matrix results and select the CIWS over the Bushmaster.

(3) Self-Defense AAW Elements Selected

(a) Evolved Sea Sparrow (ESS) Missile and MK 91 Fire Control System

The ESS missile is anticipated to be a greatly improved local AAW defense missile which is based upon the current RIM-7M Sea Sparrow missile. The ESS would incorporate totally new components for the rocket motor, aerodynamic control system, and auto-pilot while retaining compatibility with vertical launch capability. These missile enhancements would greatly improve its kill probability against future ASCMs which will operate at higher speeds and with greater maneuverability. The system would normally be operated in conjunction with the MK 23 TAS for target tracking and assignment. The MK 91 FCS can accept designations from a variety of

sensors including surface/navigation radars, infrared detection systems, and OCL systems. (The MK 91 FCS would receive OCL cueing, filtered through local tactical computer assets, as alerts for probable outer defense leakers). However, the MK 91 system would still need to develop the fire control problem to support mid-course missile guidance. The ESS missile uses semi-active mid-course guidance with both IR and anti-radiation terminal homing. Two dual MK 91 radar illuminators would be installed on the CMX to provide the ESS guidance and illumination signals. The dual "headlight" configuration of the MK 91 installation contains one antenna for transmitting and one antenna for receiving. Significant characteristics are included in the following tables:

ESS Missile Characteristics	
Range	10-20 nm (max)
Speed	approx. 2.5 Mach
Length	145.7 in
Weight	540 lbs
Diameter	9 in
Warhead	90 lbs HE
Cost	~$150K

MK 91 Fire Control System Installation & Characteristics	
Weight	14430 lbs
Volume	480 ft^3
Average Electric Power	unknown
Cost	unknown

(b) MK 15 CIWS Phalanx

Two close-in weapons system (CIWS) systems would be installed to provide extremely close-in, last-ditch AAW self-defense for the CMX. CIWS is a self-contained weapon system. The system contains its own search and track radar (VPS-2), fire control system and 20 millimeter gatling gun. The system can operated independently in an automatic mode and can also receive designation sectors from other sensors. Interfaces with other CMX sensors would be incorporated to ensure a smooth hand-off of any local self-defense "leakers." Maximum range is 2 nautical miles with an effective range of 0.8 nautical miles. Rate of fire is 3000-4500 rounds per minute with approximately 1500 rounds in the magazine. The entire system weighs 12446 pounds and has a working circle of 216 inches.

(c) MK 36 Mod 2 SRBOC

Chaff and other decoys are employed for defensive deception of enemy radars, particularly homing radars of anti-ship cruise missiles (ASCM). Each MK 36 Super Rapid-Blooming-Chaff (SRBOC) launcher consists of six 130 mm tubes. Cartridges available are Torch IR decoy, Super Chaffstar, Super Hiram III/Super Hiram IV(IR), and Super Gemini RF/IR. Chaff or decoy launch could be initiated manually or automatically during ASCM defensive reaction modes.

b. Self-Defense ASUW Elements

(1) Harpoon (AGM/RGM/UGM-84)

As previously discussed, Harpoon would be used in conjunction with the CEC/OCL concept. In addition, the CMX would have the capability to launch Harpoon independently to support ASUW self-defense.

(2) Tomahawk

A previously discussed, CMX would have the capability to initiate Tomahawk launches independently or to respond to a launch command to support the CEC/OCL concept. The CMX would also have the capability to launch Tomahawk independently to support ASUW self-defense.

c. Self-Defense ASW Elements

(1) Surface Ship Torpedo Defense Phase 1

Phase I of the Surface Ship Torpedo Defense system employs passive defense by utilizing a trailed underwater acoustic emitter. The current phase 1 system is the improved Nixie SLQ-36. The installation at the CMX fantail would include a pair of winches with two Nixie bodies. Each towed body is approximate 6 inches by 31 inches. The decoys would trail the ship through ports in the transom. Only one decoy would be operated at a time, although two would be installed for redundancy.

5. Aviation Elements

The CMX would posses the capability to carry an embarked helicopter or an unmanned aviation vehicle (UAV). While UAVs are used by foreign navies for tactical reconnaissance, there are no UAVs in use which have attack capability. Such UAVs are technologically feasible in the near future and thus remain a candidate for the CMX combat system. Conventional helicopters, such as the SH-60B/F have proven to be versatile and capable performers in the Fleet. Recent Gulf War experience has indicated the effectiveness of attack helicopters such as the AH-1W Seacobra for ships operating in littoral waters.

The CMX aviation elements employed would be selected based on the deployment mission and the assessment of the Fleet CINC's operational commander. The CMX would be able to carry helicopters up to the size of the SH-60B/F.

C. EVALUATION OF SELF-DEFENSE COMBAT SYSTEM

The Combat System, as defined above, was evaluated against expected threats to determine its capability to protect the CMX from anti-ship missiles that leak through the outer air defenses of the task force. The threat weapon models developed by the Design Team, are representative of the likely threat missiles the CMX would encounter (see Appendix B). These threat missiles were used to conduct the evaluation of the combat system for the CMX.

1. Threat Parameters

The following table from Appendix B, lists the characteristics of the threat missiles that were used to evaluate the combat system performance of the CMX:

Table 4-4. Enemy Threat Weapons

Designated Name	Radar Cross-section (m^2)	Speed (Mach)	Range (nm)	Warhead Weight (kg)	Guidance	Profile Trajectory
Trasher (A-S)	0.05	2.5	40	10	Passive Radar	Homes on Radar
Takeover (A-S)	0.7	3.4	300	1000	Active or Passive Radar	High Altitude w/50° terminal dive to target
Seagull (S-S)	0.11	0.7	15	110	Active Radar	15 meter sea skimmer
Sunstroke (S-S)	0.2	2.5	65	50	Active Radar	10 meter sea skimmer
Small Mines	R=1 ft			500		moored mine
Spikefish Torpedo	533mm dia.	60 kts	25000 yds	500	Active and Passive SONAR	Gyro turn, straight run, search then home

The Trasher missile is an air launched high speed anti-radiation missile designed to suppress the radars of a target. The warhead is small at 10 kilograms but designed to destroy the relatively unprotected antennas of the radar system.

The Takeover missile is an air launched anti-ship missile with active radar guidance and a large 1000 kilogram warhead. It cruises to the target at an altitude of 50,000 feet with a terminal dive to the target at a 50° angle and is designed to sink or severely disable ships through its large blast effect and penetrating warhead.

The Seagull missile is a ship or air launched subsonic sea skimming anti-ship missile. It has a semi-armor piercing warhead of 110 kilograms. It uses active radar for guidance and is designed to disable a ship by blast damage within the hull of the ship.

The Sunstroke missile is an air or surface launched high speed sea skimming anti-ship missile. The warhead is relatively small at 50 kilograms but the high speed of the missile decreases the likelihood that it will be shot down. Also, the warhead is designed to disable a ship by blast effects.

2. CMX Combat System Parameters

In this section, parameters of the CMX engagement elements were analyzed to evaluate the effectiveness of the CMX self-defense combat system. The results of four Anti-ship Missile Defense (ASDM) engagements are presented. From the results of the saturation engagement of an AEGIS cruiser (see Blue Water Engagement scenario, Chapter II, Section B), the maximum number of leakers the CMX would be expected to engage is 3 missiles. Only AAW threats were analyzed. This does not imply that the ASW, ASUW or mine-countermeasures defense areas are not important or not in need of study. Resources and time constraints, however, preclude similar studies in these areas. The basic methodology presented in this report would also be used to study these other defensive warfare area.

For point-defense, the CMX would use a combination of defensive weapons. The proposed electronic warfare system is the SLQ-32(V3) which features threat warning, active jamming and automatic threat engagement capabilities. The proposed defensive missile system is

the Sea Sparrow system. While the Evolved Sea Sparrow system is proposed for installation in the CMX, the characteristics of this system are largely unknown except that the new missile will be more capable than the current missile. Thus, this evaluation was conservative in nature. The final layer of self-defense is the MK 15 Phalanx Close In Weapons System (CIWS). The characteristics of the self-defense engagement elements are listed in the following table:

Engagement Element	Speed	Maximum Range (nm)	Minimum Range (nm)	Method of Kill
SLQ-32(V3) w/CHAFF, TORCH	---	---	---	Active jamming, false targets
MK 15 CIWS	3650 fps	0.81	0.05	Impact
VLS Sea Sparrow	1.5 Mach	8	0.75	Proximity fused warhead

The probability of kill (Pk) of each engagement element against each threat was estimated to be as follows:

Table 4-5. CMX Engagement Elements' Probability of Kill (Pk)

Threat Missile	MK 15 CIWS	SLQ-32(V3) w/CHAFF,TORCH	VLS Sea Sparrow
Trasher	0.3	0.1	0.7
Takeover	0.8	0.4	0.8
Sunstroke	0.5	0.4	0.6
Seagull	0.7	0.4	0.7

3. Assumptions And Definitions

In general, the inbound target was assumed to be non-maneuvering, with the exception of the terminal flight prior to impact. Also, a target hit was considered to be a kill of the incoming threat. It was also assumed that the combat system would be in full readiness condition.

(1) Radar Horizon: For the threats considered a conservative assumption was made that the radar antennas would be located 50 feet above the surface of the ocean. The radar horizon equation is given by:

$$rh = 1.23\left(\sqrt{H_{tgt}} + \sqrt{H_{radar}}\right)$$

where: rh = radar horizon in nm

H_{tgt} = height of target above surface in feet

H_{radar} = height of own ship radar above the surface in feet

Using an assumed target height of 30 feet the radar detection distance was 15.75 nm.

(2) Operational Arcs: The ship's weapon and sensor array were assumed to have a 360° arc of fire and detection capability.

(3) Engagement rules: To determine whether a particular threat could be engaged, the following timing rules were used:

(a) A minimum of ten seconds time delay was assumed from the time of detection to the time of classification, and assignment to the fire control system.

(b) A minimum of 2 seconds time delay was assumed from the time of assignment to the fire control system, to the time the first missile would be launched.

(c) The minimum launch interval would be 1 second between missile launches.

(d) A minimum of 4 seconds was used from the time-of-kill assessment to the time of weapon re-engagement.

(e) The threat missiles would be engaged at the maximum range of the self-defense system.

(f) The threat missiles would be detected at a range of 50 nm or the radar horizon which ever would be applicable.

(g) All threat missiles would be launched at their maximum range.

(h) The ship's self-defense engagements would be serial in nature and would not interfere with each other.

(4) Definition of kill--The incoming threat would either be caused to miss the ship or be damaged to such an extent that the warhead and/or debris of the missile would present no threat to the ship systems or personnel.

4. Threat Engagement Profiles

In this section, engagements of the four threat missiles against the CMX combat system were analyzed. In these analyses, the probability of killing the threat missile was calculated for the

CMX defensive system engaging the incoming missile. For multiple missiles launched at the CMX, it was assumed that each missile would be engaged such that they would not interfere with each other, and the CMX self-defense systems would not be saturated by the incoming missile raid.

The engagements are presented in time line format, with t=0 at the threat impact time, and positive values representing the time to impact of the threat missile. These time lines are shown in detail in Appendix D. A summary of the timelines is also included at the end of this section. The timeline was analyzed until the threat had theoretically impacted the ship. This method allowed analysis of weapon system capabilities in terms of reaction times and capability of engaging the threat to the time of impact.

a. Trasher Missile Engagement

The Trasher missile was launched at its maximum range of 40 miles at an altitude of 5000 feet which is about 4000 feet above the radar horizon at a distance of 40 miles. The missile was detected 5.9 seconds later at a range of 37.3 miles. Ten seconds later the missile was classified as a threat and assigned to the fire control system for engagement. The SLQ-32 automatically engaged this immediate threat and began active jamming and launched CHAFF. Forty six seconds from impact, the ship launched a Sea Sparrow missile with another launched one second later. These two missiles engaged the inbound missile at 8.0 and 7.9 miles,respectively. Four seconds later the combat system had determined if it had killed the incoming missile and if it had not, it would launch another set of two missiles 12 and 11 seconds before impact. These missiles engaged the threat at ranges of 2.1 and 1.9 miles respectively. Finally at a range of 0.81 miles the

MK 15 Phalanx Close in Weapons System engaged the target for 0.8 seconds. The cumulative kill probability for this threat missile was;

$$Pk = 1-(1-0.1)(1-0.7)^4(1-0.3) = 0.994897$$

If three such missiles were launched at the CMX the expected number of hits would be

$$\#hits = 3(1-0.994897) = 0.015309$$

b. Takeover Missile Engagement

The Takeover missile was launched at its maximum range of 300 miles at an altitude of 50,000 feet. The missile was detected at a range of 50 miles, 84 seconds before impact. Ten seconds later the missile was classified as a threat and assigned to the Fire Control System for engagement. Seventy two seconds before impact the SLQ-32 began active jamming and fired CHAFF. The missile began its dive 17.2 seconds before impact. The fire control system recalculated the intercept solution and fired Sea Sparrow missiles at 14 and 13 seconds before impact. These missiles intercepted the inbound missile at a range of 2.7 and 2.5 miles. At a range of 0.8 miles and 1.3 seconds before impact the MK 15 CIWS engaged the target. The total Probability of kill for this engagement was;

$$Pk = 1-(1-0.4)(1-0.8)^2(1-0..8) = 0.995$$

If three missiles were launched at the CMX the expected number of hits would be

$$\#hits = 3(1-0.9952) = 0.0144$$

c. Seagull Missile Engagement

The Seagull missile was launched at its maximum range of 15 miles and it immediately descends to an altitude of 15 meters. It was detected 110 seconds before impact at a range of 14.3 miles. Ten second later it was classified as a threat and assigned to the Fire Control System to be engaged. At 90 seconds before impact the SLQ-32 began active jamming and launched CHAFF. The probability of kill for this engagement was 0.4. Two Sea Sparrow missiles were also launched at this time, one second apart. These missiles intercepted the incoming missile at a range of 8.0 and 7.9 miles respectively. Because this missile was relatively slow six additional Sea Sparrow missiles engaged the target at ranges of 5.0, 4.9, 2.9, 2.8, 1.4 and 1.3 miles. Finally the MK 15 CIWS engaged the target 6.3 seconds before impact at a range of 0.8 miles. The total probability of kill for this engagement was

$$Pk = 1 - (1 - 0.4)(1 - 0.7)^8(1 - 0.7) = 0.999988190$$

If three missiles were launched against the CMX the expected number of hits would be

$$\#hits = 3(1 - 0.9999881902) = 0.0000354291$$

d. Sunstroke Missile Engagement

The Sunstroke missile was launched at its maximum range of 65 miles and immediately descends to an altitude of 10 meters. This threat was detected 32 seconds before impact at the radar horizon of 14.9 miles. Ten seconds later the missile was classified as a threat and assigned too the fire control system for engagement. At a range of 9.3 miles and 20 seconds before impact the SLQ-32 began active jamming and launches CHAFF. Also, at this time, two Sea Sparrow

missiles were launched, at a one second interval. These missiles intercepted the target 7.5 and 7.1 seconds before impact. Finally the MK 15 CIWS engaged the threat 1.7 seconds before impact at a range of 0.81 miles. The probability of kill for this engagement was

$$Pk = 1 - (1 - 0.4)(1 - 0.6)^2(1 - 0.5) = 0.95$$

If three missiles were launched at the CMX the expected number of hits would be

$$\#hits = 3(1 - 0.952) = 0.141$$

5. Threat Engagement Summary

In summary, the CMX is capable of meeting the minimum probability of kill against each on the threat missiles. The Sunstroke missile presents the biggest threat to the CMX. However this type of missile, while under development in several countries, is currently not in any inventory. In addition, the self-defense missiles carried by the CMX will certainly evolve beyond the current Sea Sparrow missile. This will enable the CMX to maintain its excellent self-defense capability against the current missiles likely to engage the CMX.

A summary of these results is provided in the following table:

Table 4-6. CMX Threat Engagement Summary

Threat Missile	CMX Probability of Kill (Pk)	Expected Number of Hits for 3 Incoming Missiles
Trasher	0.995	0.015
Takeover	0.995	0.015
Seagull	0.99999	0.00004
Sunstroke	0.952	0.141

D. COMBAT SYSTEM DEFINITION SUMMARY

Candidates for elements of the CMX combat system were selected from open sources. Characteristics of the candidates systems were analyzed both quantitatively and qualitatively by the Design Team. The elements which survived the selection process were then evaluated against probable future threats. The evaluation section clearly demonstrates the high effectiveness of the CMX combat system. However, further analysis beyond the scope of this project would be required to evaluate the effectiveness of the CEC and OCL elements selected.

The table below, summarizes the element selection for combat system functional areas resulting from the tradeoff studies of various candidate systems.

Table 4-7. Combat System Element Tradeoff Selection

	Elements Considered	Elements Selected
Surface Search & Navigation	AN/SPS-55 SN/SPS-65 AN/SPS-67 AN/SPS-64 AN/SPQ-9(i) Radiant Mist Furuno	AN/SPS-64 Radiant Mist
Electronic Warfare	SLQ-32(V2) SLQ-32(V3) WLR-1(H)	SLQ-32(V3)
Air Search & Tracking	AN/SPS-48 AN/SPS-49 MK 23 TAS	MK 23 TAS
AAW Self-Defense Engagement	RIM-7 ESS RIM-116 RAM Stinger MK 45 5" Gun MK 75 76mm Gun MK 15 Phalanx CIWS MK 38 Bushmaster Goal Keeper	RIM-7 ESS MK 15 Phalanx CIWS

The following table summarizes element selection for combat system functional areas for which detailed tradeoff studies were either not required based on the TOR/ORD requirements or were beyond the scope of this project:

Table 4-8. Combat System Element Selection (No Tradeoff)

Aviation/Navigation Support	RAYCAS V TACAN (Replacement System) AN/WRN-6(V) GPS AN/SRN-25 Omega AN/WSN-5 AN/WQN-1(V)
Command, Control & Communications (C^3)	ACDS Link 16 Link 11 Model 5 OTCIXS AN/USQ-64(V)7 TADIXS AN/USQ-64(V)8 & AN/USQ-101 CUDIXS OCL System 1 IVCS AN/UYK-43 Computers (Next Generation) MK 7 ORTS AN/USQ-119A(V) 10B Tactical Graphics System NAVMACS II AN/UGC-143A(V) NST OK-455(V) UHF DAMA AN/UYQ-62 C2P VER 1 Link Processor AN/WSC-3(V)3 UHF SAT Transmitter/Receiver AN/USC-38 EHF SATCOM TSECK/KWR-46 Crypto Equipment TSECK/KG-84A SATCOM Crypto TSECK/KG-84C Crypto Equipment AN/USC-43 ANDVT TACTERM AN/USC-43 ANDVT SATCOM R-2368A LF/MF/HF Receiver HF Broad Band VHF (30-88) VRC-46 RPL VHF (115-156) Upgrade UHF Basic Radios UHF AJ HAVE QUICK

Table 4-8. Combat System Element Selection (No Tradeoff) (Cont.)

OCL/CEC Engagement	SM-2 Tomahawk (TLAM & TASM) Harpoon (ASCM)
AAW Self-Defense Engagement	MK 36 Mod 2 SRBOC
ASUW Self-Defense Engagement	Tomahawk (TLAM & TASM) Harpoon (ASCM)
ASW Self-Defense Engagement	Surface Ship Torpedo Defense Phase I

V. FEASIBILITY STUDIES

Feasibility Studies are a series of top level tradeoff studies which determine the relationship between military effectiveness and cost of new ship design concepts. The studies considered the military effectiveness of sensors and weapons, speed, endurance, survivability, reliability, maintainability and other factors related to the mission requirements. The goal of the Feasibility Studies was to identify alternative ship concepts that offered balance between cost and military performance, from which tradeoff studies were conducted to determine which was best.

Having determined the major payload of the ship in the Combat System Definition in terms of specific elements, their size, weight, volume, power and service requirements were used as a starting point for determining the ship's hull mechanical and electrical characteristics. These determinations were made using the NAVSEA, computer based, ship design program known as the Advanced Surface Ship Evaluation Tool (ASSET).

Using known ship characteristics, based on operational requirements, payload definition and other ship design concepts such as hull type, main propulsion, electrical distribution, (etc.), ship configuration data banks were established in the program, one for each specific ship configuration to be analyzed, from which computational modules were executed. These modules addressed specific area of ship design, including hull geometry, hull structure, resistance, propulsion, machinery, weight, space, hydrostatics, seakeeping, manning and cost. The output of the program was the iteratively calculated, converged solution of the major ship characteristics for each configuration.

Sections A and B of this chapter discuss the scope of design concepts considered for the CMX and model configurations used to analyze these concepts, and the outputs of the analyses produced by ASSET. Sections C and D present the tradeoff analysis and final ship design concept selected which was developed for the CMX.

A. DESIGN CONCEPTS CONSIDERED

This section presents a description of the ship design concepts considered for the CMX. It was not the intention of the Design Team to consider all possible aspects of modern ship design in this project, but rather to explore a range of design options that would represent a well rounded survey, on which to base the Feasibility Studies.

Many factors limited the scope of options to be studied with primary consideration given to the:

- Ship Design Philosophy
- Ability to model the design in ASSET
- Amount of design data available
- Time constraints

The following sections describe the design options. Prominent features or advantages of the options are presented which justify their consideration. In some cases, comparison of more than one option was sought, in others, decisions were made by the Team to eliminate options from consideration. Not all of these options are applicable to all, or any one, design configuration(s).

1. Hull

a. Hull Types

The hull types considered can be grouped in two broad classes; destroyer/cruiser and auxiliary hulls. Based on the results of the scenario and ROM studies it was apparent that this

vessel would not be much larger than 10,000 long tons and would need to have a sustained speed greater than 26 knots. These features in addition to the limitations of the analysis tools, influenced the design team's decision to investigate using a cruiser/destroyer hull. Within this class of hull type, there were a number of standard hulls from which to begin the analysis. We selected two hull forms, the DD 963 and the DDG 51. The auxiliary hulls were not in the available data base, however they were shown to be unable to meet the speed requirements of the CMX.

b. Double Bottom

The use of a double bottom improves vessel survivability, provides a convenient fuel stowage location and adds structural members which strengthen the hull girder. For these reasons we examined this feature in our feasibility study design.

c. Hull Flare

The use of hull flare has been shown to have the beneficial effects of reducing the reflected signature of the ship and improving seakeeping ability. The DDG-51 has 10° of flare to reduce its signature. The Design Team chose to analyze a similar flare as well as perpendicular side walls.

2. Main Propulsion

a. Drive Mechanism

Two major drive mechanisms were examined. The first, was a conventional main engine, mechanically connected to the shaft via reduction gears. For the configuration of a single main engine room (discussed in the following machinery room arrangements section), a cross-connect gear was assumed to be installed. Mechanical drive has the advantage of low technical risk and

good reliability. However, it requires a great deal of hull volume since all elements of the drive train, with the exception of the propeller, must be contained within the hull and must be aligned in an inflexible way.

The use of electric drive with podded propulsion was also considered. In this configuration, the drive train consists of two main engines with generators, electrical cabling and podded propulsors containing main propulsion motors. The primary advantages of podded electric drive propulsion are; greater flexibility in engineroom placement, greater operational flexibility, reduced ship service generator requirements, and improved propeller performance. The first three advantages also contribute to a more survivable ship design. The disadvantages are; greater technical risk (particularly associated with the generator cooling and the pod connections) and possible increased ship draft.

b. Main Machinery Room (MMR) Arrangement

Two variations of main machinery rooms were analyzed. A conventional two MMR arrangement and a single MMR were considered for the mechanical propulsion ships. Traditionally, two main machinery room arrangements perceived to provide enhanced survivability. Recent analysis as discussed in Rains,1992, has challenged this perception and a one engineroom configuration, with the engineroom located low and as far aft in the ship as possible, may improve the survivability of the vessel. Furthermore, combining the main machinery into a single room reduces the amount of hull volume occupied by propulsion systems, allowing for a smaller vessel and/or increased payload.

The Electric Drive/Podded Propulsion vessel was analyzed with a two main machinery room configuration. The Design Team felt that the need to protect the interconnecting cabling

did not compromise survivability. To the contrary, the Team felt that the flexibility in placement of these two main machinery rooms provided for potential optimization with respect to survivability considerations. In addition, separating the main engines distributed the electrical generating capability.

c. Main Engines

The choices for main propulsion were limited to gas turbine and diesels based on the results of the ROM Studies. It was decided that nuclear propulsion, for political and economical reasons, was not a viable option. Conventional steam propulsion was ruled out due to high manning requirements, low power-to-weight ratio, and demanding preventive maintenance requirements. Gas turbine and diesel engines were considered with two possible configurations, a conventional 2 MMR ship and a single MMR ship.

3. Electrical Distribution

a. Generators

A variety of generators was considered, including diesels, gas turbine and propulsion derived. It was anticipated that the generators would not have a significant impact on the conventional ship configurations, therefore different generator selections would be considered so as to maximize power density and reduce maintenance and training requirements. Use of generators types already existing in the fleet would support these goals.

b. Propulsion Derived Ship Service Power

Propulsion derived ship service power has several advantages: improved fuel economy, improved engineroom layout flexibility, and improved survivability. The disadvantages are: use of

unproven technology, social resistance to a new generation scheme, and relatively unknown reliability and maintainability. The PDSS ship is expected to have reductions in weight, volume and cost. This option was considered in conjunction with the electric drive ship to achieve greater flexibility in speed reduction.

4. Auxiliaries

a. Dispersed

Conventional ship designs are configured with centralized auxiliaries. There is usually extensive interconnecting piping, and numerous fittings exist which permit isolation of damaged sections and system reconfiguration via cross-connection. To limit the size and weight which auxiliary systems add to the ship, and to improve survivability, the Team considered incorporating the use of dispersed auxiliaries into the CMX design.

b. Zonal Auxiliaries

Zonal Auxiliaries is typified by the co-location of the major auxiliary systems with the systems that are being serviced. The systems are sized to handle the local load, and are repeated when multiple loads exist throughout the ship. For example, rather than having one Electronics Cooling system for the entire ship, a separate system exists for each major zone or enclave. This arrangement improves survivability, since the support systems will be located near the components serviced. Damage may be localized to a particular area within an enclave and other enclaves would not be affected. This configuration may introduce additional maintenance requirements, therefore the systems used will need to be carefully selected.

5. Materials

a. Hull

Material selection can play an important role in the cost and weight of the ship. The Design Team examined the effects of using different materials for the hull. Mild and High Tensile Strength (HTS) were considered.

b. Superstructure

Historically, the design standard for superstructure blast overpressure had been 3 psi. Beginning with the DDG-51, the Navy has begun to use 7 psi as the blast standard. Commensurate with this requirement, the Design Team decided to use the 7 psi standard.

c. Piping

Advances have been made in the applications of composite materials for ship's piping. Significant weight reductions can be achieved by the use of composites in piping systems. The design team examined the effect of using composite piping in the ROM study of Appendix B, however ASSET does not model this concept.

6. Steaming Requirements

a. Range

The CMX would be forward deployed for a large portion of its operational life. Moreover, it may spend significant time on station and would need to have a range similar to the vessels with which it may be deployed. The amphibious vessels have ranges on the order of 8000

miles. This was selected as the desirable range. A minimum desired range of 6000 miles was established to ensure that the CMX would be no more range limited than current combatants in the fleet.

b. Speed

As established by the Requirements Document, the speeds for the CMX were considered as follows:

- Cruise Speed -- the speed on which endurance range is based. The required cruise speed was 20 knots.
- Sustained Speed -- the speed at which engine load is equal to 80% of rated capacity. With a required sustained speed of 28 knots, the Design Team established a minimum sustained speed of 26 knots to permit design flexibility.
- Maximum Speed -- the speed achieved at full load on the main engines. The Design Team established no maximum speed requirement.

B. ASSET MODELS

The ASSET (Advanced Surface Ship Evaluation Tool) software, was developed by Boeing under contract from David Taylor Research and Development Center and the Naval Sea Systems Command. It is a compiled FORTRAN program which allows a ship design team to interactively synthesize the various aspects of ship design in a real time computing environment. The program is composed of multiple modules which include hull geometry, hull structure, hull subdivision, ship resistance, propulsion, machinery analysis and arrangement, weight, space, hydrodynamics, cost analysis, sea keeping analysis and manning analysis. The naval architecture and machinery modules may be run under a synthesizing control program which iterates the design until all aspects converge to within a specified tolerance. The CMX Feasibility Studies were conducted using the ASSET program.

The Rough Order of Magnitude (ROM) studies cited in Chapter 2 and contained in Appendix B to this report provided the initial input for the ASSET feasibility study models. Specific operational requirements, combat system payload, and ship design philosophy were interactively combined within the framework of the design concepts described in the previous section. Further, historical hull form and machinery arrangement data served to constrain the bounds of the feasibility study. As a result of this synthesis of requirements, capabilities and desires, three CMX ship models were developed for analysis.

This section includes a description of these three models and the parameter variations analyzed with each model which incorporated the design concepts previously discussed. The outputs from the ASSET runs follow.

1. Models

a. CMX 1

CMX 1 defines the baseline ship model for CMX feasibility studies. The CMX 1 model was derived from the Spruance class destroyer hull form and machinery arrangement. While Spruance class destroyers have two MMRs, each of which contain two LM2500 gas turbine engines driving one propulsion shaft, CMX 1 has only one LM1600-VAN2 gas turbine engine driving one propulsion shaft, in each main machinery room. The LM1600-VAN2 is a regenerative gas turbine which has a rated output power of 26,250 HP. This use of one gas turbine engine per shaft departs from the standard Navy practice as exemplified by the Spruance class destroyer, the Oliver Hazard Perry class frigate, the Ticonderoga class AEGIS cruiser, and the Arleigh Burke class AEGIS guided missile destroyer. However, because the gas turbine engine has been proven to be highly reliable, we decided that one per shaft was sufficient.

All Spruance class combat system elements were removed from the ASSET model payload database, and replaced with a new combat system payload database that incorporated the elements selected for the CMX (see Chapter 4). Of particular note, the CMX 1 baseline model has six VLS banks each of which contain SM-2, Tomahawk, vertically launched ASROC, and vertically launched Evolved Sea Sparrow missiles. Other major combat system detection and engagement elements included in the CMX 1 model are:

- Radiant Mist electro-optical surface search and track sensor
- AN/SPS-64 navigation and surface search radar
- MK 23 TAS (and air search radar)

- SLQ-32 (V3) ESM/ECM system
- Two MK 15 Vulcan Phalanx CIWS
- MK 91 Fire Control System with two dual directors
- ACDS with Link 11 (model five) and Link 16
- Offboard Command Launch System 1
- Hanger, crew and logistics support for aviation assets of size, up to the SH-60B/F

CMX 1 employs three Allison DDA-501-K34 gas turbine generators each rated at 2500 kW to provide ship service electrical power. This model incorporates features currently required by the latest Navy standards, in addition to some which may be required by future standards or achieved by probable technological advances. These features include the following:

- Controllable pitch propellers
- Trail shaft operation at endurance speed for fuel economy
- Gas turbine exhaust infrared suppression
- Exclusive use of 60 Hz electrical distribution (no 400 Hz)
- 7 psi superstructure blast overpressure design
- Partial Collective Protection System (CPS)
- Modern Vidmar cabinet spare parts stowage
- Current habitability and berthing standards
- Minimal superstructure size for reduced detection signature
- Reduced manning concepts
- Very low noise (<84 dB) engine enclosures

b. CMX 2

CMX 2 uses the CMX 1 hull form, payload and systems, but CMX 2 was arranged with one main machinery room containing both LM1600-VAN2 propulsion engines.

Additionally, variants of CMX 2 were run using diesel engines for main propulsion. Configurations using two engines per shaft and one engine per shaft were modeled.

c. CMX 3

CMX 3 incorporates the same payload as CMX 1 and CMX 2. However, its hull form was derived from the DDG 51 class instead of the Spruance class destroyer. The CMX 3 hull has greater flare and greater beam at the main deck level as compared to CMX 1 and CMX 2. CMX 3 further departed from CMX 1 and CMX 2 (and current ships) by using podded electric drive for main propulsion. The CMX 3 machinery arrangement utilized two main machinery rooms.

CMX 3 uses the same LM1600-VAN2 propulsion turbines as the previous CMX models. Each of the two LM1600-VAN2 turbines are used to drive a propulsion generator and a 2500 kW Variable Speed Constant Frequency (VSCF) cyclo-converter generator. The propulsion generators power a propulsion bus which supplies power to the two electric drive pods. The propulsion generators are the alternating current (AC) synchronous type with liquid cooled stators and air cooled rotors. The AC power from the propulsion generators is rectified prior to the propulsion bus. The electric drive motors are direct current (DC) type, and a helium refrigeration system was incorporated to provide supercooling of the DC pod motors. Each propulsion pod drives a contrarotating propeller system. The propeller system was attached to the forward end of the pod to improve the flow stream characteristics into the propellers and thereby improve

propeller efficiency. The forward propellers have five blades and the after ones have seven blades in order to provide torque balance and hydrodynamic efficiency.

As noted above, two 2500 kW VSCF generators provide propulsion derived ships service (PDSS) power. Additionally, two Allison DDA-501-K17 gas turbine generators each rated at 2500 kW are installed in separate auxiliary machinery rooms (AMR). These generators are installed transversely in order to reduce the AMR volume and area consumed by the AMRs.

2. Parameter Variations

CMX 1 was established as the baseline model for the feasibility studies. Each CMX model, however has a baseline configuration from which the following parameter variations were analyzed.

a. Number of VLS Modules

The baseline ship for each CMX model includes six VLS modules. A five VLS module variant was modeled and analyzed to determine marginal ship impact.

b. Steaming Requirements

Ship endurance range was modified from 8000 nautical miles to 7000 nautical miles for each of the three CMX models.

c. Waste Heat Boilers

Electric waste heat elements were substituted for waste heat boilers for each of the three CMX models.

3. Model Outputs

The following tables provide the principle characteristics of each CMX model configuration, and the parameter variations for each model, as determined using the ASSET program.

For the CMX 2 diesel configuration, the two engines (one per shaft) proved too large vertically, for the size engineroom provided in the baseline CMX 2 model. When smaller engines were used (two per shaft), it became difficult to fit the four engines in the single machinery room ship. The net effect of using diesel propulsion engines was an increase in displacement of approximately 2000 LT. Since these results have significant negative impact on the CMX design, no table is provided.

Table 5-1. CMX 1 Model Summary

PRINCIPAL CHARACTERISTICS		CMX 1 Baseline	CMX 1 with Reduced Payload (5 VLS)	CMX 1 with Reduced Range (7000 nm)	CMX 1 with Electric Heat vice Waste Boilers
LBP	feet	592	577	579	592
BEAM (DWL)	feet	61.8	60.3	60.4	61.8
BEAM Weather Deck	feet	61.8	60.3	60.4	61.8
DEPTH Station 10	feet	47	45.8	45.9	47
DRAFT (DWL)	feet	20.1	19.6	19.7	20.1
GM_T	feet	6.4	6.6	5.7	6.4
C_p		0.55	0.55	0.55	0.55
C_x		0.82	0.82	0.82	0.82
Δ (light ship)	tons	6,655	6,120	6,320	6,655
Δ (full load)	tons	9,520	8,840	8,890	9,520
V_e	knots	20	20	20	20
Range	nm	8,000	8,000	7,000	8,000
V_{ss}	knots	28.4	28.6	28.6	28.4
V_{max}	knots	29.8	30	30	29.8
Hull Volume	ft^3	1.1×10^6	1.0×10^6	1.0×10^6	1.1×10^6
Superstructure Volume	ft^3	6.6×10^5	6.4×10^5	6.4×10^5	6.6×10^5
24 Hour Average Electric Load	kw	2,050	1,900	1,974	2,050
Average Cost	$M	468	448	454	468

Table 5-2. CMX 2 Model Summary

PRINCIPAL CHARACTERISTICS		CMX 2 Baseline	CMX 2 with Reduced Payload (5 VLS)	CMX 2 with Reduced Range (7000 nm)	CMX 2 with Electric Heat vice Waste Boilers
LBP	feet	592.6	578.7	580.5	592.8
BEAM (DWL)	feet	61.9	60.5	60.7	61.9
BEAM Weather Deck	feet	61.9	60.5	60.7	61.9
DEPTH Station 10	feet	47	45.9	46.1	47.1
DRAFT (DWL)	feet	20.2	19.7	19.8	20.2
GM_T	feet	6.3	6.6	5.7	6.4
C_p		0.55	0.55	0.55	0.55
C_x		0.82	0.82	0.82	0.82
Δ (light ship)	tons	6,686	6,186	6,415	6,686
Δ (full load)	tons	9,559	8,901	8,984	9,571
V_c	knots	20	20	20	20
Range	nm	8,000	8,000	7,000	8,000
V_{ss}	knots	28.5	28.6	28.6	28.5
V_{max}	knots	29.9	30	30	29.9
Hull Volume	ft^3	1,102,069	1,026,493	1,035,754	1,103,206
Superstructure Volume	ft^3	61,149	59,357	59,581	61,373
24 Hour Average Electric Load	kw	2,150	1,994	2,074	2,255
Average Cost	$M	471.2	451.7	459.1	471.1

Table 5-3. CMX 3 Model Summary

PRINCIPAL CHARACTERISTICS		CMX 3 Baseline	CMX 3 with Reduced Payload (5 VLS)	CMX 3 with Reduced Range (7000 nm)	CMX 3 with Electric Heat vice Waste Boilers
LBP	feet	555.3	539.8	551	554.8
BEAM (DWL)	feet	57.7	56.1	57.3	57.7
BEAM Weather Deck	feet	66.8	64.9	66.3	66.7
DEPTH Station 10	feet	44.1	42.9	43.7	44
DRAFT (DWL)	feet	18.4	17.9	18.3	18.4
GM_T	feet	3.8	4	3.6	3.8
C_P		0.56	0.56	0.56	0.56
C_X		0.82	0.82	0.82	0.82
Δ (light ship)	tons	6,111	5,618	6,060	6,079
Δ (full load)	tons	7,844	7,207	7,662	7,820
V_c	knots	20	20	20	20
Range	nm	8,000	8,000	7,000	8,000
V_{ss}	knots	29.4	29.5	29.4	29.3
V_{max}	knots	30.7	30.8	30.7	30.7
Hull Volume	ft^3	1,048,584	963,346	1,024,729	1,045,641
Superstructure Volume	ft^3	56,986	54,997	56,451	56,942
24 Hour Average Electric Load	kw	2,059	1,893	2,030	2,159
Average Cost	$M	453.5	432.7	449.6	451.2

C. TRADEOFF STUDY

1. Model Selection

The tradeoff matrix for the model selection between CMX 1, CMX 2 and 3 is presented on the following page. Salient selection factors are discussed below.

Average ship costs for CMX 1 and CMX 2 were within one percent for comparable parameter variations. CMX 3 cost decreases were greater than three percent. Thus, CMX 3 is rated most favorable in the cost design factor.

All three CMX models were run using six VLS modules. ASSET, however does not incorporate the exact dimensions of the VLS modules into the volume calculations. As a check of the ASSET models, the actual areas and volumes for the VLS modules were compared to those output from the model runs. As a result, although the ASSET program converged on a solution for CMX 1, with six VLS modules, the Team felt that only five VLS modules would actually fit in the CMX 1 hull. Therefore, the CMX 1 model was given a lower rating for CEC/OCL Effectiveness than CMX 2 and CMX 3.

All CMX models had the same self-defense capabilities and were judged to have equally superior self-defense capability.

CMX 1, with two main spaces and conventional mechanical arrangement and shafting, was rated low in survivability. CMX 2, with both main engines in one main space and conventional mechanical arrangement and shafting, was rated as average. CMX 3 was rated above average in survivability due to its separated main spaces, lack of mechanical shaft alleys,

Table 5-4. CMX Model Selection

DESIGN PRIORITY	Weight Factor	CMX 1	CMX 2	CMX 3
Cost	1	2	2	1
CEC/OCL Effectiveness	1	2	1	1
Self-Defense Effectiveness	1	1	1	1
Survivability/Vulnerability	1	3	2	1
Manning Reduction	1	3	2	1
R, M and A	0.4	2	2	3
Future Growth/Upgrade	0.4	2	2	1
Standardization	0.4	1	2	3
Commercial Off the Shelf (COTS)	0.4	2	2	2
Detection Signature	0.4	2	2	1
Environmental Impact	0.2	2	2	2
Specifications	0.2	3	2	1
Appearance	0.2	2	2	2
Habitability	0.2	2	2	2
Political/Societal Issues	0.2	2	3	3
Weighted total		16.8	14.2	11

redundant propulsion electrical power cabling and reduced sonar and synthetic aperture radar detectability achieved through flow improvements related to its podded propulsion.

With two main spaces for a small-to-moderate sized ship, CMX 1 would be expected to require above average manning. CMX 2 would require average manning. Due to projected reliability of electric drive systems, and the requirement for depot level vice organization level maintenance of the actual propulsion pods, CMX 3 would require lower manning than its mechanical drive counterparts.

The inability to perform at-sea organization level repairs to the podded propulsion components is viewed as a greater negative effect than the projected positive effect of improved reliability. Thus, CMX 3 is rated lower than CMX 1 and CMX 2 in R, M & A.

The first generation electric drive system is expected to have greater potential for future growth and upgrade as compared to the relatively mature technology of mechanical drive.

CMX 1 would employ standard two machinery room layout of reduction gearing and shafting. However, electric propulsion is currently not a Fleet standard. Thus the CMX 3 rating suffers in this area.

All CMX variants were judged to have equal and average COTS utilization factors.

CMX 3 offers several advantages over the conventional mechanical drive ships. As noted above, the podded propulsors are expected to be less detectable by sonar or by synthetic aperture radar. The contrarotating propellers will face a more ideal flow stream due to lack of shafting and support struts in the forward flow path. Due to reduced propeller loading, each contrarotating propeller is sized smaller than a single conventional propeller. Thus for a given RPM at a smaller

diameter, propeller tip velocities will be reduced. This results in reduced cavitation. The orientation of the propulsion pods will reduce trailing vortices and other normally distinguishable wake characteristics. Due to the arrangement flexibility afforded by electrical transmission as compared to mechanical transmission, the main machinery spaces can be separated greater distances along the length of the ship. The adjoining exhaust ducting and hot gases will be more distributed as compared to conventional ships. This results in a reduced probability of IR detection in any one "search" area. Additionally, the more widely separated IR characteristics may "confuse" the IR homing device in an enemy anti-ship cruise missile.

With regard to specifications (weights, volumes, power requirements, etc.), CMX 1 was rated low due to the weights associated with the conventional mechanical drive. CMX 2 was slightly improved with its reduced shafting and gearing requirements. CMX 3 was rated above average due to the weight and volume reduction achieved with electric podded propulsion.

CMX 2 and 3 were rated lowest with respect to political/societal issues due to their unconventional configurations. CMX 1, with its single engine per shaft, was rated average.

All three CMX models were rated equal with respect to the other design priority factors had no effect on the overall CMX selection. No significant discussion points are noteworthy.

Based on the discussion above and the tradeoff matrix, CMX 3 is the most desirable model.

2. Parameter Variations

Results of the ASSET runs demonstrating the parameter variations are shown on the following pages.

The following table shows the percent changes resulting from the model parameter changes. Electric heat showed little change for both CMX 1 and 2 due to their similar configurations, and was deleted from the CMX 2 column. For comparison, however, the changes for the diesel configuration of CMX 2 are included.

The figures show these results in a bar graph format, comparing the actual values of the ship characteristics.

These results show that the parameter changes result in more desirable ship characteristics for all models, however no variations of models CMX 1 or CMX 2 is more desirable than CMX 3 baseline.

Table 5-5 ASSET Models, Parameter Changes (% Delta)

SHIP MODEL	CMX 1 Standard DD MR Arrangement				CMX 2 Single Engine Room				CMX 3 Podded Propulsion			
Parameter Variation	*CMX 1* Baseline *Reference*	5 VLS Cells	Range 7000 nm	Electric Heat	CMX 2 Baseline	5 VLS Cells	Range 7000 nm	Diesels	CMX 3 Baseline	5 VLS Cells	Range 7000 nm	Electric Heat
L.S. Disp (LT)	*6,645*	-7.2%	-4.9%	0	+0.5%	-6.9%	-3.5%	+18.1%	-8.1%	-15.5%	-8.8%	-8.5%
F.L. Disp (LT)	*9,521*	-7.9%	-6.7%	0	+4.0%	-6.5%	-5.6%	+8.9%	-17.6%	-24.3%	-19.5%	-17.9%
LBP (ft)	*592*	2.5%	-2.2%	0	0	-2.2%	-1.9%	+2.9%	-6.3%	-8.8%	-6.9%	-6.3%
Vsust (kt)	*28.4*	0	0	0	0	0	0	-2.8%	+3.5%	+3.8%	+3.5%	-3.6%
Avg. Cost (1992)	*470*	-4.3%	-3.0%	0	0	-3.4%	-2.0%	0	-3%	-7.5%	-3.8%	-3.6%

Figure 5-1a. Parameter Changes

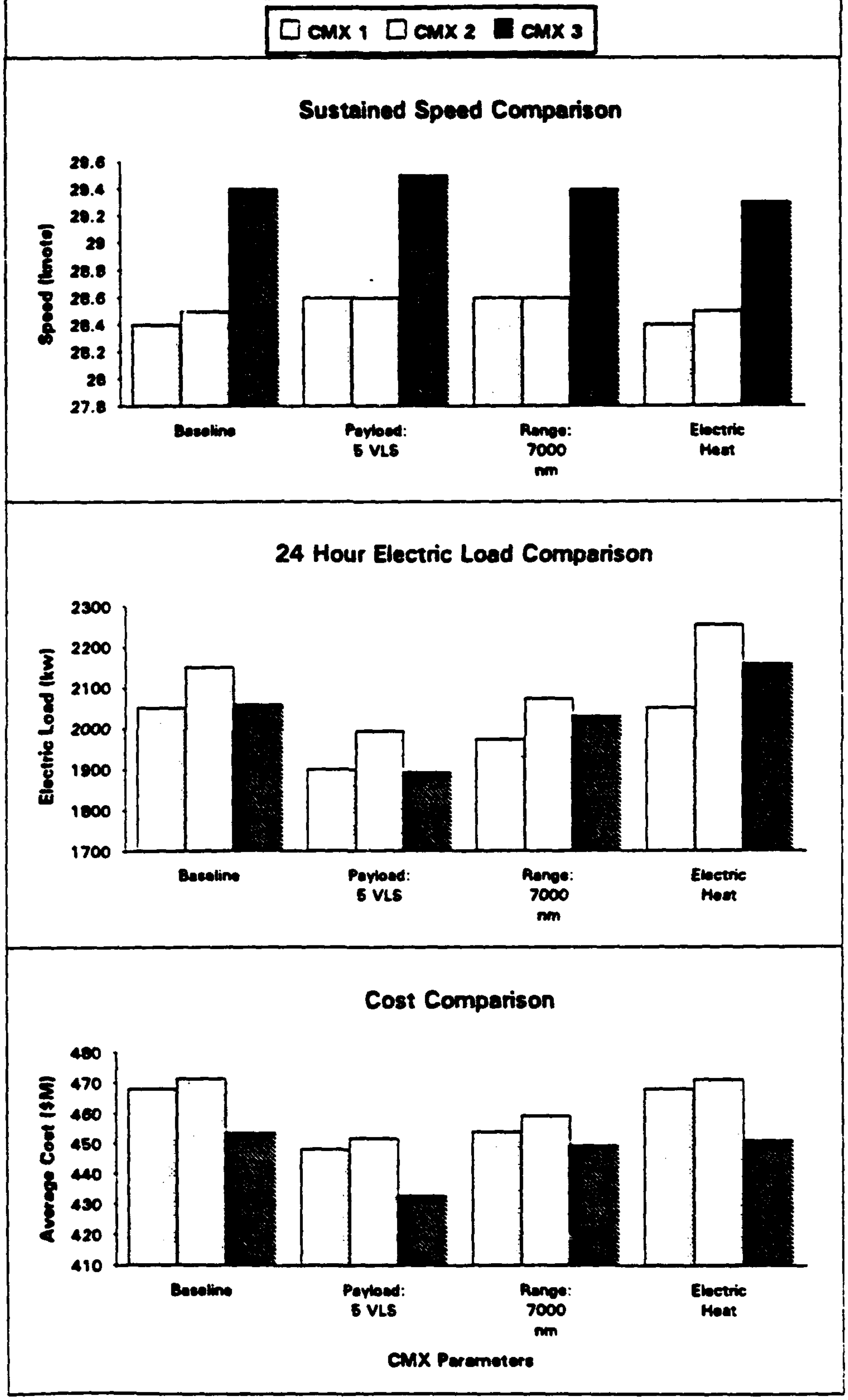
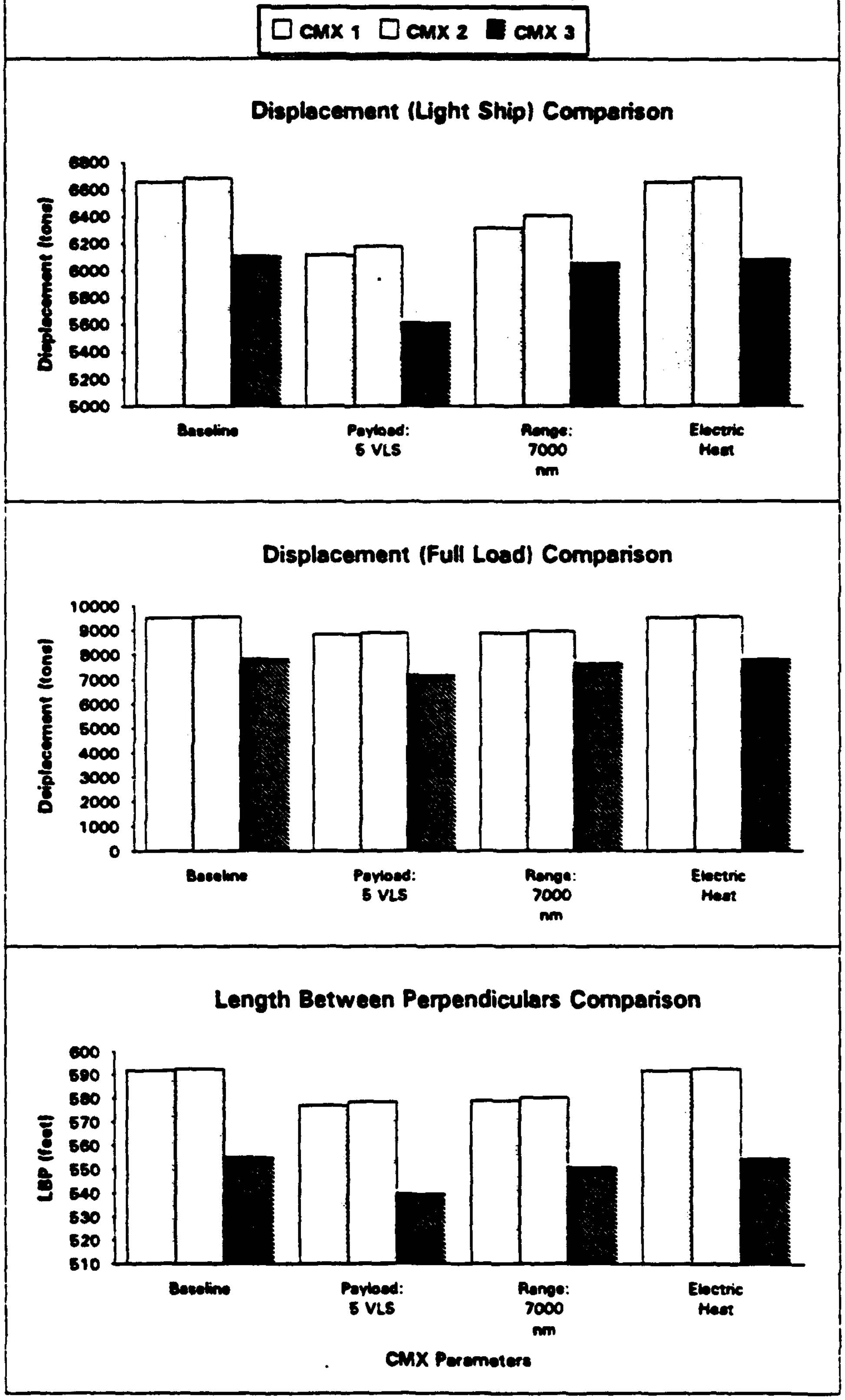


Figure 5-1b. Parameter Changes



D. FINAL DESIGN CONCEPT

As described in the previous section, the model selected for the CMX design was that of CMX 3 (heretofore referred to as CMX). The discussion below, describes additional ASSET analyses that were done to arrive at the final synthesized CMX hull, upon which the Preliminary design would be developed:

- Enlarging the superstructure forward and adding superstructure aft near the after-MMR uptakes. This provides more superstructure than specified by ASSET, however, it was felt that this was necessary since ASSET historically underestimates the amount required. The after deckhouse allowed the intakes to be higher above the waterline to minimize seawater ingestion, and provides some of the volume required for a helicopter hangar.
- Fixing the values for manning and accommodations.
- Determining the size, type and number of turbine generators.
- Estimating the expected size and weight of the C^3 systems.
- Positioning of the transverse watertight bulkheads to accommodate the desired VLS bank arrangement, and meet the enclaving and floodable length requirements.

VI. PRELIMINARY DESIGN

In the Preliminary Design Phase of the ship design process, the model selected through the Feasibility Studies is further developed in sufficient detail to facilitate establishing Contract Design Specifications.

The objectives of the preliminary design are to quantify ship performance, refine design estimates and reduce or eliminate major risks. Through the course of this phase the following design baseline elements are established:

- Detailed ship geometry
- Combat system baseline
- Lines and arrangement drawings
- Intact and damaged stability analysis
- "Three digit" weights
- Master Equipment List (MEL)
- Class "C" cost estimate

This chapter presents the detailed development of the CMX model selected through the Feasibility Studies (Chapter 5). These detailed discussions reference the ASSET model output for the Final Design Concept CMX, which is included in Appendix F.

For the purpose of this project, to limit the scope of the preliminary design phase for the CMX, only specific areas of the elements listed above will be developed in this chapter. These areas include a discussion of the Combat System Architecture and development of the Hull,

Mechanical and Electrical systems design (sections A and B). The Naval Architecture analysis is presented in section C. Sections D and E are the Ship Arrangements drawings and Enclaving concept, and a discussion of the Manning Organization is included in section F.

A. GENERAL COMBAT SYSTEM ARCHITECTURE

This section presents a detailed description of the physical and functional characteristics of the combat system architecture developed for the CMX. While the Combat System Definition (Chapter 4) outlined various specific equipments which would be installed in the CMX, selected primarily from the pool of systems available today, this section discusses how the Design Team postulated these systems may be incorporated into the CMX using technology which is currently being developed or may be available by the year 2010.

Included in this section are the combat system physical and functional block diagrams, ctional flow diagrams and descriptions, and a discussion of the battle organization for the CMX.

1. Combat System Integration and Management

The Design Team postulated a very advanced, highly integrated combat system for the CMX. It would take advantage of the tremendous leaps currently being made in computational power and system integration. There would be a relatively small Combat Information Center (CIC), which would function as the primary control station for all ship self-defense and OCL functions. A separate Maintenance Control Center/Auxiliary Combat Information Center (MCC/ACIC), located in a separate enclave, would provide limited redundancy. It would function primarily as the maintenance control center, but would contain sufficient equipment to provide OCL functions if there were damage to CIC.

To the maximum extent possible, all consoles would be identical in appearance, but be configured for different functions as provided by host software for the console. This concept postulates the development of a Standard Multi-function Console (SMC), consisting of a reconfigurable tablet or keyboard section, and a monitor section. The screens would be touch sensitive to allow the use of a pointer or finger to activate commands. The console would be programmable with rule-based expert knowledge, and configured with scanning modules enabling it to recognize specific users and tasks. The current overabundance of console types and variations could be reduced by the development of an SMC.

All major elements would be connected via fiber optic data buses. A scaled down version of the highly acclaimed National Data Highway, the bus contains multiple parallel paths controlled by two independent workstations functioning as servers, providing reconfiguration and processing capability. Rapid developments in fiber optics hold the promise of incredibly large bandwidths in a reliable, secure and flexible environment. Wiring would be dramatically reduced. The use of distinct, distributed parallel busses could improve the survivability of the vessel.

A Combat System Operating Program (SYS-OP) was postulated, which would allow operators in CIC to remotely control the operation and employment of the combat system in all modes and report the status of all combat system elements to a Combat System Readiness Logic System (SYS-READ) program. The operators in MCC/ACIC would monitor the combat system readiness via the SYS-READ, and provide secondary control of the SYS-OP system.

Specific capabilities and requirements of the systems and components described above are detailed in the following sections.

a. Embedded Support System Requirements

The combat system for the CMX would require significant support services. This would include 60 Hertz electrical power, chilled water, sea water, ventilation including humidity control and high pressure air. Significant piping weight reductions and improved survivability can be achieved by the use of zonal auxiliaries. The CMX would have two auxiliary system zonal modules, each with a complete set of auxiliaries (including electrical generation), capable of supporting the ship's primary OCL mission (see Hull, Mechanical and Electrical section). The Engineering Control Center/Damage Control Center (ECC/DCC), would monitor the status and direct the operation of this equipment through similar systems to the SYS-OP/SYS-READ, configured for the engineering plant (see Hull, Mechanical and Electrical section).

b. Readiness Assessment, Fault Detection and Identification Requirements

As indicated in the previous section, control, operation and monitoring of the combat system would be accomplished through the use of the SYS-OP/SYS-READ program systems. SYS-READ would interface with SYS-OP and use the status reports generated by each component to make an assessment of the combat system readiness. It would constantly monitor processing performance and reassign processors based on system time lags. Processes would be prioritized and it would recognize low priority routine events such as programmed maintenance during combat situations.

SYS-OP would coordinate an embedded fault detection system. Failure of components would be flagged and diagnostic routines, incorporated in the software, would be run in the background or directly by the operators in MCC/ACIC. The equipment could be monitored for

performance, both on a simplistic level (i.e., *is the equipment on?*), or up to a more sophisticated level such as power surges, ground fault detection or fiber optic splice failures.

Through SYS-READ, automated status logic could report the ship's readiness rating directly to the Commanding Officer and higher authority, provide an input for work requests or provide an equipment run time input for scheduling maintenance. Beyond providing status, SYS-READ could also provide indications of equipment operating condition, impending failure, required maintenance and provide recommendations for equipment reconfiguration in failure conditions or under battle damage. The system could also provide the capability to accomplish an emergency function when a missile hit is impending. If the ship is damaged, the SYS-READ could provide updated status to ECC/DCC and provide recommendations to the operators, via SYS-OP.

c. System Readiness Logic

The SYS-OP/SYS-READ program systems would satisfy the detailed Test Requirements Analysis document which would be developed in the final stages of preliminary design. Thus, SYS-READ would both determine that a fault conditions exists with a given element and the location of the fault. At this level, SYS-OP/SYS-READ would assign a readiness rating to each major element of the combat system. The elemental ratings would follow the standard mission readiness rating system which is established by NWP 10-1-11, Status of Resources and Training System (SORTS). These ratings are displayed in the following table:

Readiness Rating Levels	
Rating	**Description of Capability**
M1	90 to 100 percent
M2	70 to 89 percent
M3	60 to 69 percent
M4	1 to 59 percent
M5	No Capability

SYS-READ would combine the element readiness ratings using pre-programmed logic algorithms and re-programmable rule-based expert system algorithms. The Combat System Readiness Logic Diagrams provide a graphic view of the readiness conditions for elements of the combat system which comprise the functional areas of detection, control, and engagement. Example Readiness Logic Diagrams for OCL, AAW (Self-defense) and ASUW (Self-defense) mission areas are shown on the following page

Figure 6-1. OCL Readiness Logic Diagram

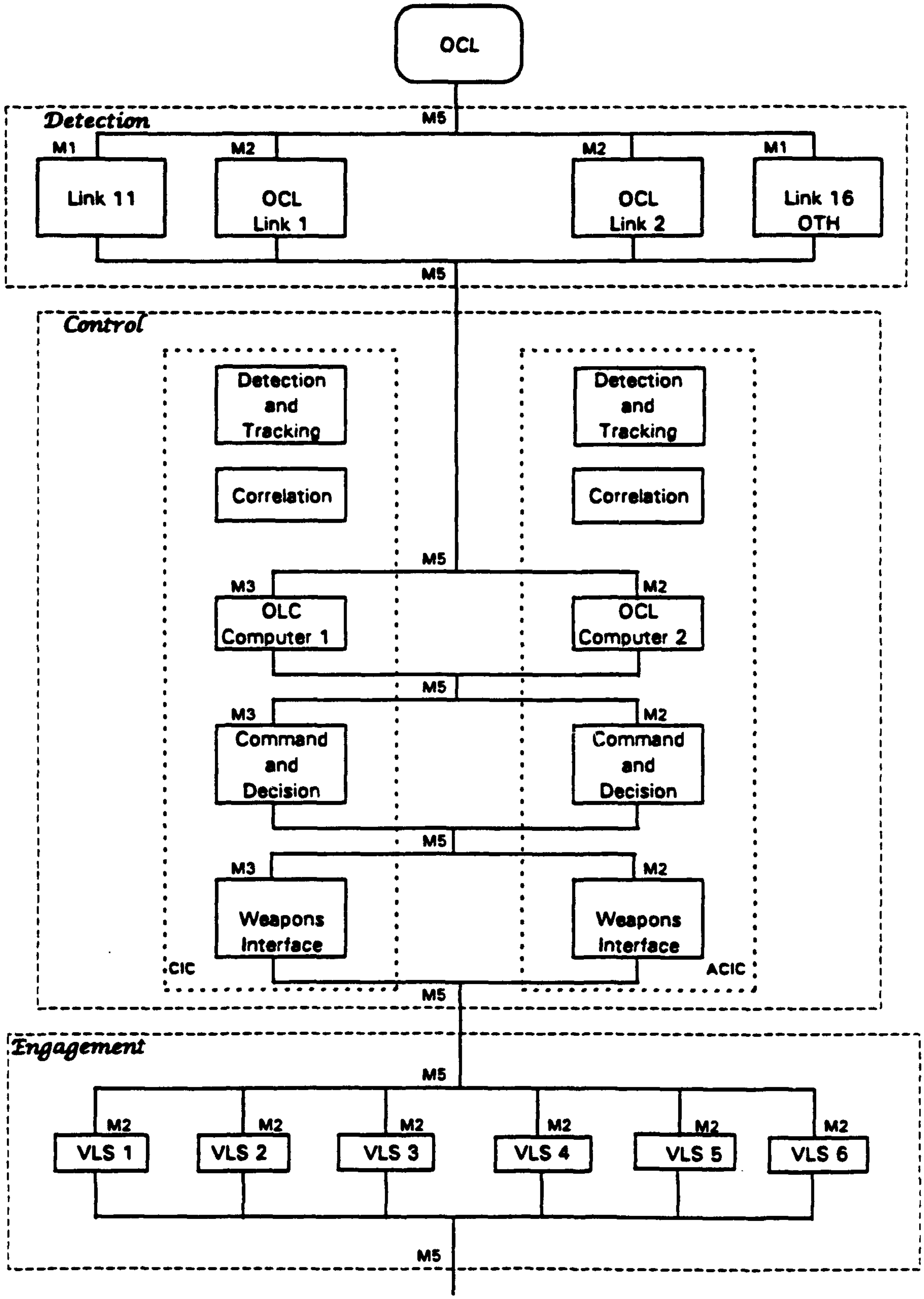


Figure 6-2. AAW (Self-defense) Readiness Logic Diagram

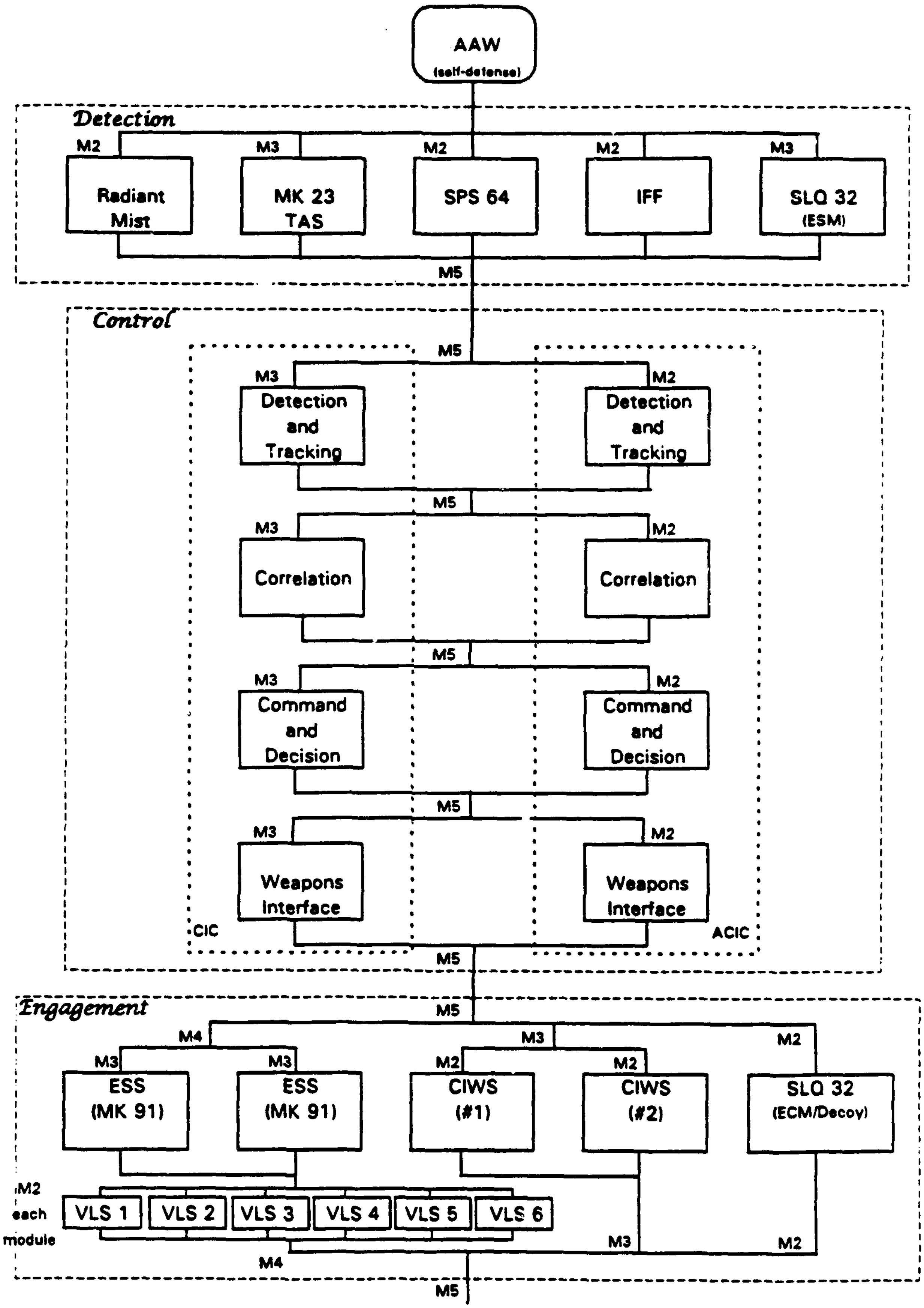
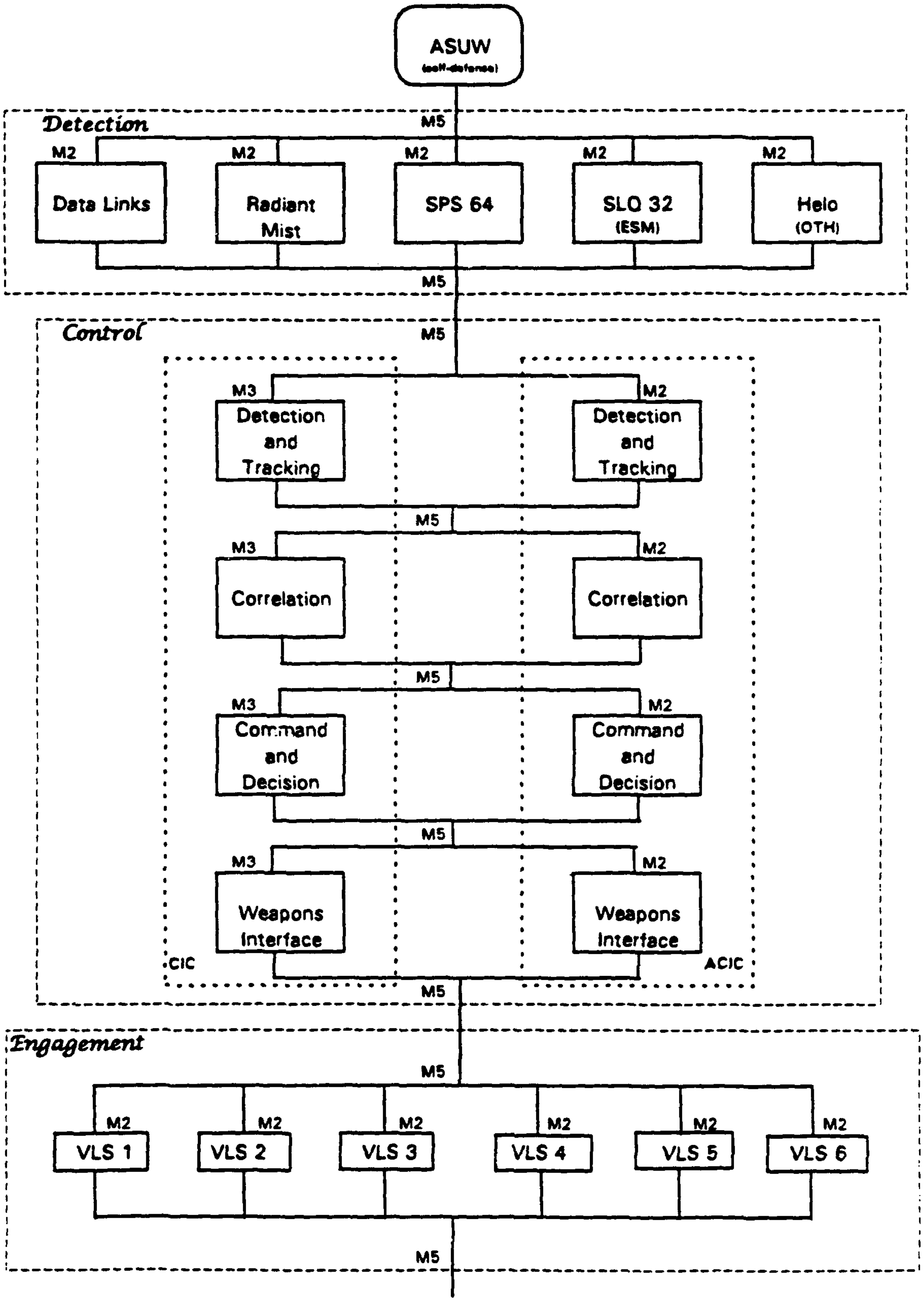


Figure 6-3. ASUW (Self-defense) Readiness Logic Diagram



d. Reconfiguration and Repair Requirements

Fault tolerance and reconfigurability are crucial for the survival of the CMX. The use of fiber optic cables would allow for multiple paths for data flows. The sequential elements would use a 'primary' data path until failure is detected. The data path would then be switched to an alternate path and SYS-OP/SYS-READ would be notified of the failure. Failure of a processor node would also be detected and an alternative processor would be selected to perform those functions. Again SYS-OP/SYS-READ would be notified of the failure. Systems similar to those of the AEGIS and MK 117 FCS would be used to allow the system to attempt a 'hot recovery' (where an alternative copy of the program with crucial data is stored in spare memory), or a 'warm start' (where the computer reloads the computer program and critical data). An additional level of reliability can be achieved by a 'hot spare' computer, where a dedicated spare computer, complete with program and data, would be ready to come on line as soon as failure is detected. The CMX would have this last feature readily available as ACIC would have a manned spare SMC ready come on line in the event that CIC is damaged beyond use (Falatko, 1990).

Security considerations would also be incorporated to allow for the possibility of deployment of nuclear capable missiles. As with conventional weapons, during combat, the Auxiliary CIC would have sufficient manning or electrically provided interlocks to allow for proper command and control of Special Weapons if CIC is lost.

e. Survivability Management Requirements

The combat system architecture is crucial in ensuring survivability. The proposed concept is to disperse the computers throughout the ship. Individual, specialized computers would be

located near the sensors whose data they process; a radar computer near the radar equipment. In addition, other specialized computers, like signal processors, would be located near the equipment they support. Thus, sensors and the serving computer are likely to be lost at the same time, following the "series-connected-equipment" survivability concept. Less specialized functions could be accomplished by multipurpose computers, which could be allocated to workstations integral with the Standard Multi-function Consoles (SMC). Loss of these computers would permit reconfiguration within the SYS-OP/SYS-READ network to restore service. These computers can be standardized and may even be commercial products ruggedized for Naval service. The use of modern multipurpose computers would enable functions to be switched as required.

f. Embedded Training Requirements

The combat system would have an embedded training capability. Scenarios would be easily programmable or available for use by the ship to provide realistic, real time training. The training module would incorporate as much of the combat system as possible. Positive control would always be provided for weapons safety. The system would be able to be interface with other ships or shore training facilities to allow task force level, integrated training. This would be especially important for the OCL capabilities.

2. Combat System Diagrams

a. Physical Architecture

The physical architecture of the CMX combat system describes the functional layout of the combat system elements from the viewpoint of the information flow and data buses. The CMX combat system data buses would be fiber optic and thus capable of virtually unlimited data bandwidth when compared to current standards. The data bus structure would be arranged in an H-architecture. Each functional information flow path (i.e. detection or control), however, would be arranged into a ring. Thus, the sensor data bus, the system information data bus, and the command and control data bus would appear as rings tied together in an H-architecture. These "rings" would exits on a single, multiplexed fiber optic data bus, separated by distinct frequencies or wavelengths and with a given bandwidth..

The physical cabling layout on the ship would be redundant to improve survivability, with two separate data buses.

Functional and physical layout of the CMX combat system architecture are shown on the following pages. The drawings are shown in the H-"ring" configuration. The physical layout drawings have been arranged by warfare area to concisely demonstrate the architecture. Further, support services such as electrical power, chill water, and service air have also been omitted for simplicity.

Figure 6-4. OCL Architecture

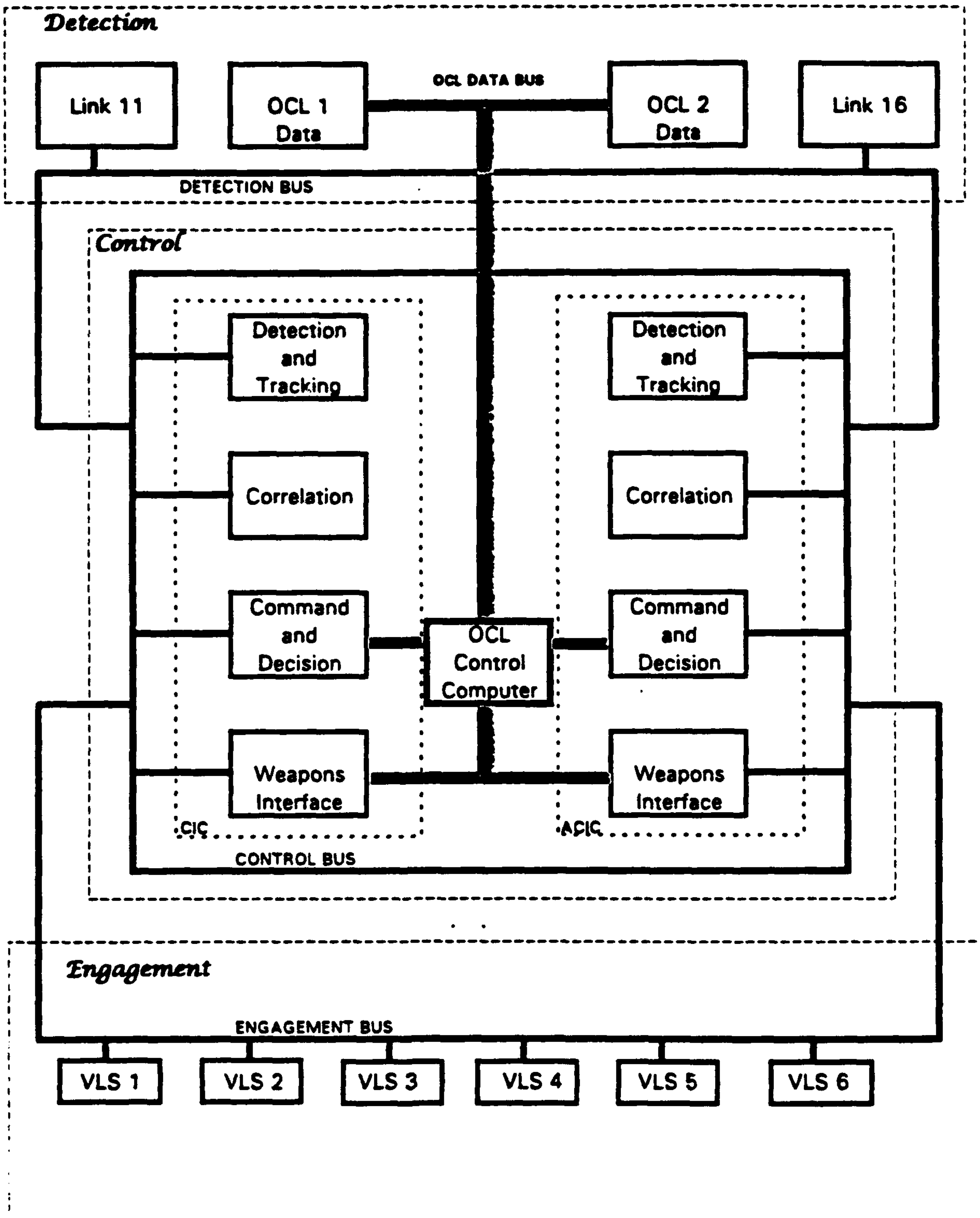


Figure 6-5. AAW (Self-defense) Architecture

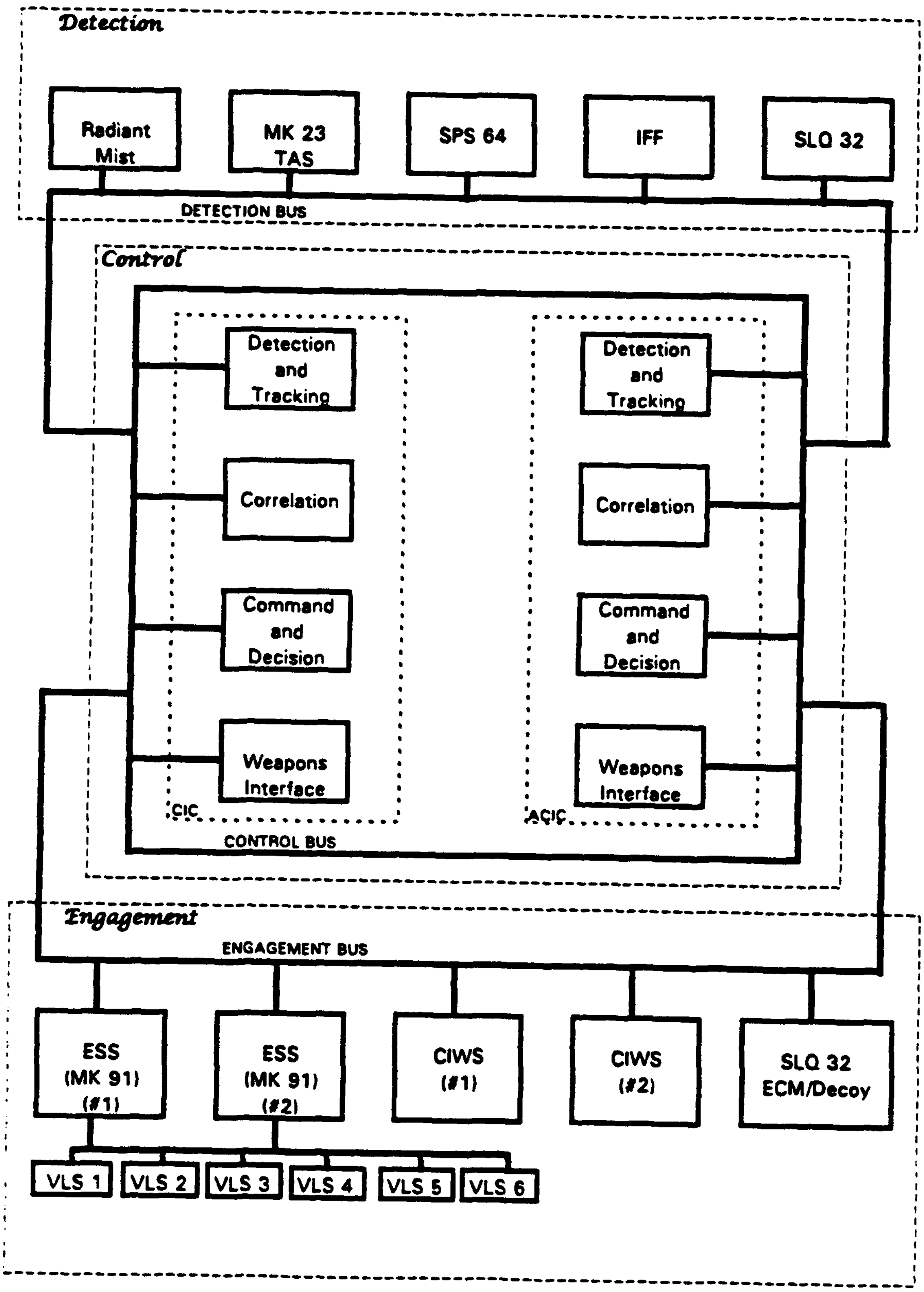
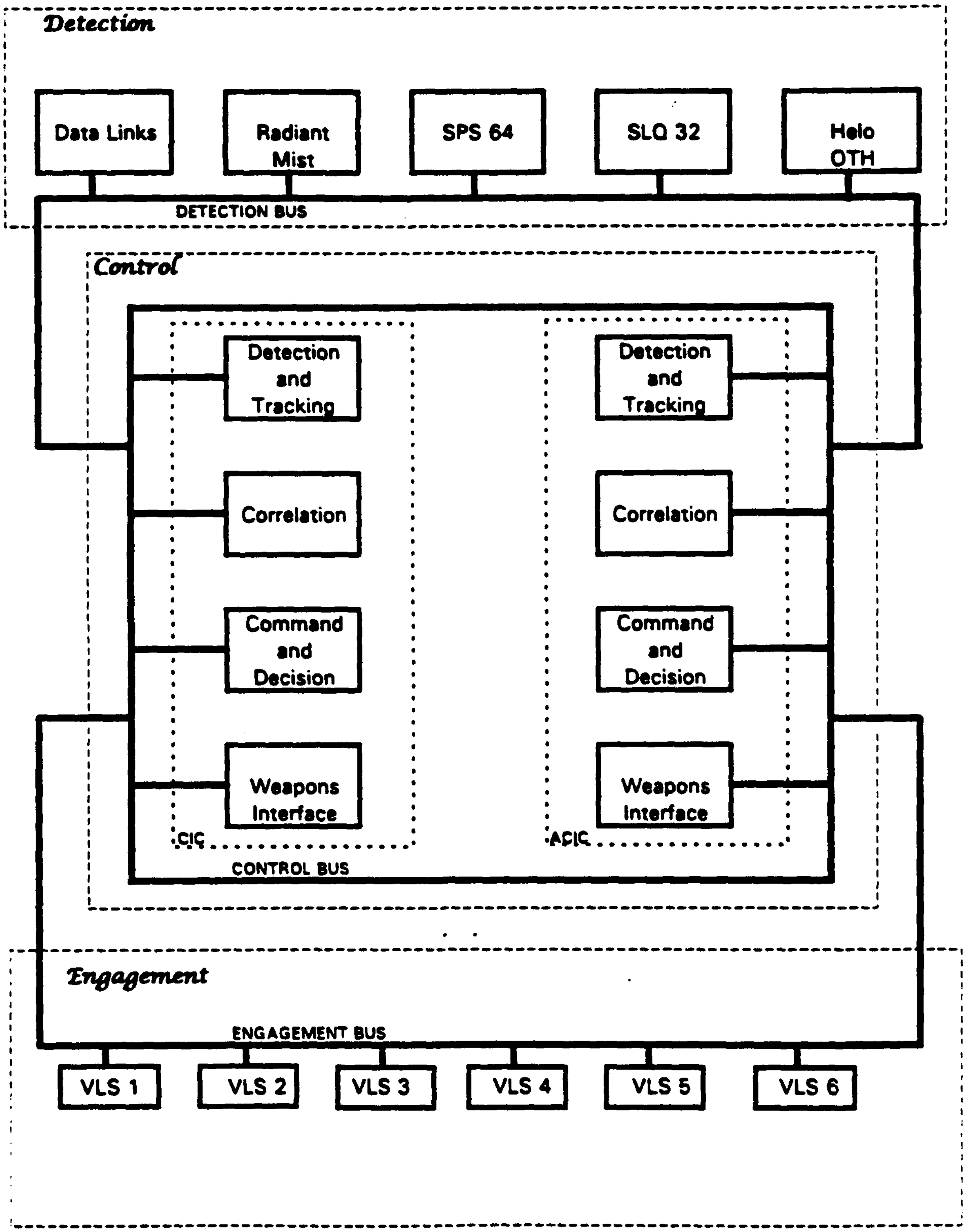


Figure 6-6. ASUW (Self-defense) Architecture



3. Functional Flow Diagrams

Functional Flow Diagrams were developed for an AAW/OCL engagement by the CMX combat system. The Tier 0 diagram provides an overview of the functional flow of system information for such an engagement. Tier 1 drawings which describe the general Tier 0 black boxes are also shown. The Functional Flow Diagrams are shown on the following pages.

Figure 6-7. Functional Flow Diagram (Tier 0)

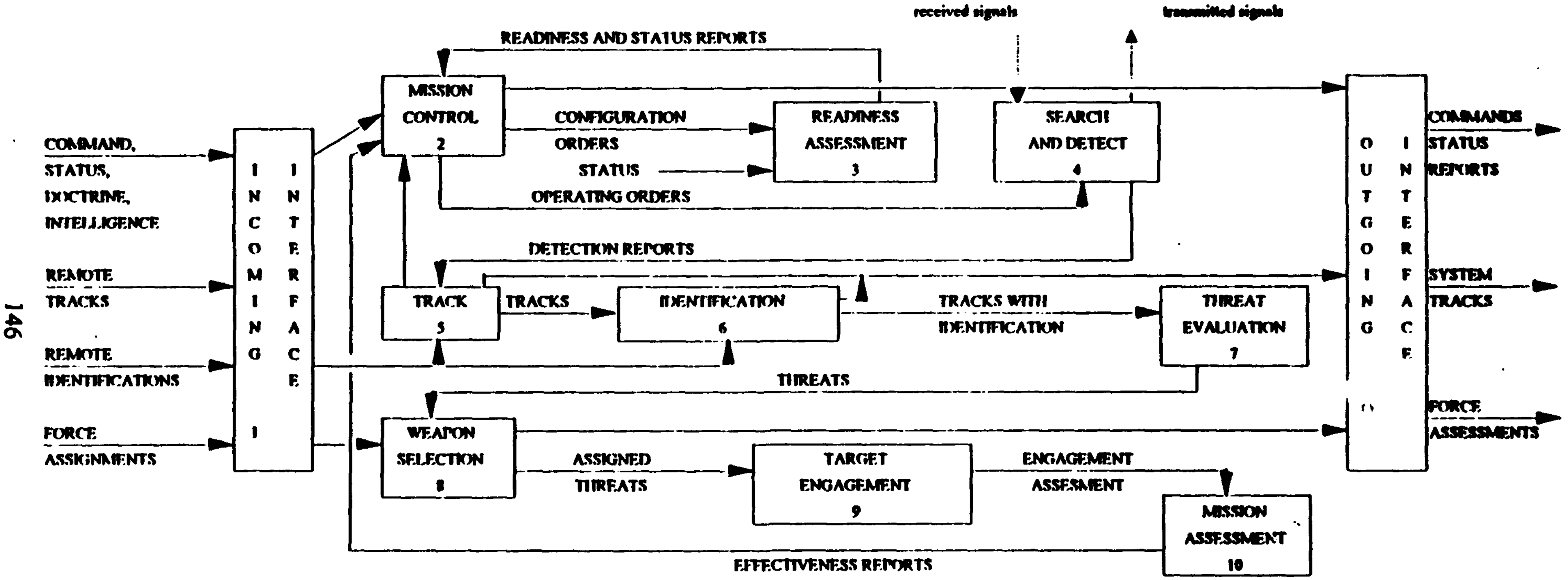
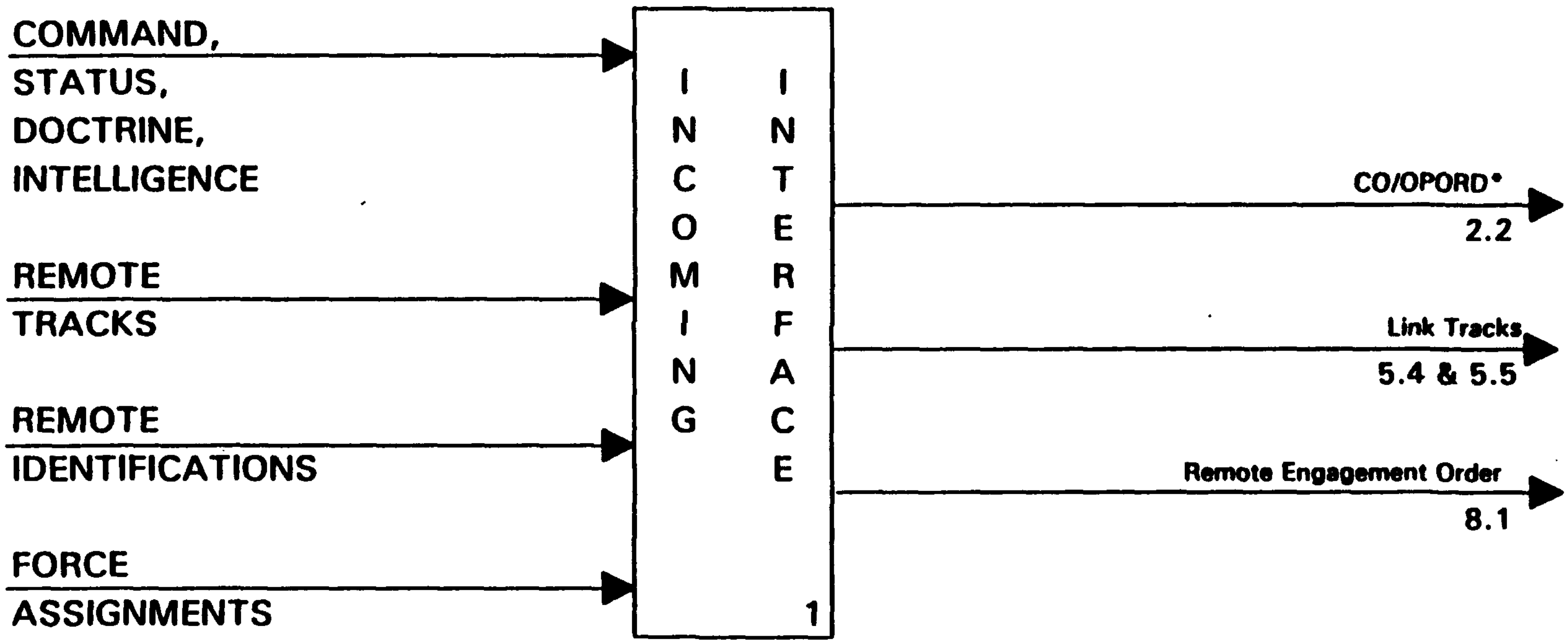
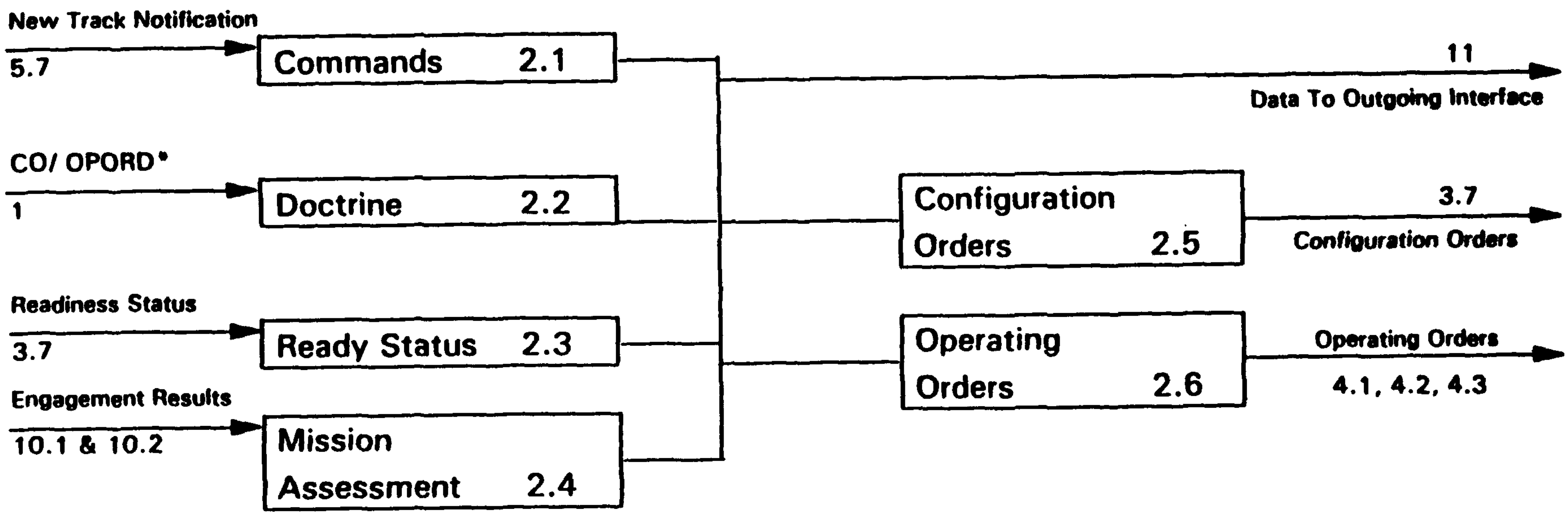


Figure 6-8a. Functional Flow Diagram (Tier 1, Block 1)



* -- COMMANDING OFFICERS STANDING ORDERS/ OPERATIONAL ORDERS

Figure 6-8b. Functional Flow Diagram (Tier 1, Block 2)



* .. COMMANDING OFFICERS STANDING ORDERS/ OPERATIONAL ORDERS

Figure 6-8c. Functional Flow Diagram (Tier 1, Block 3)

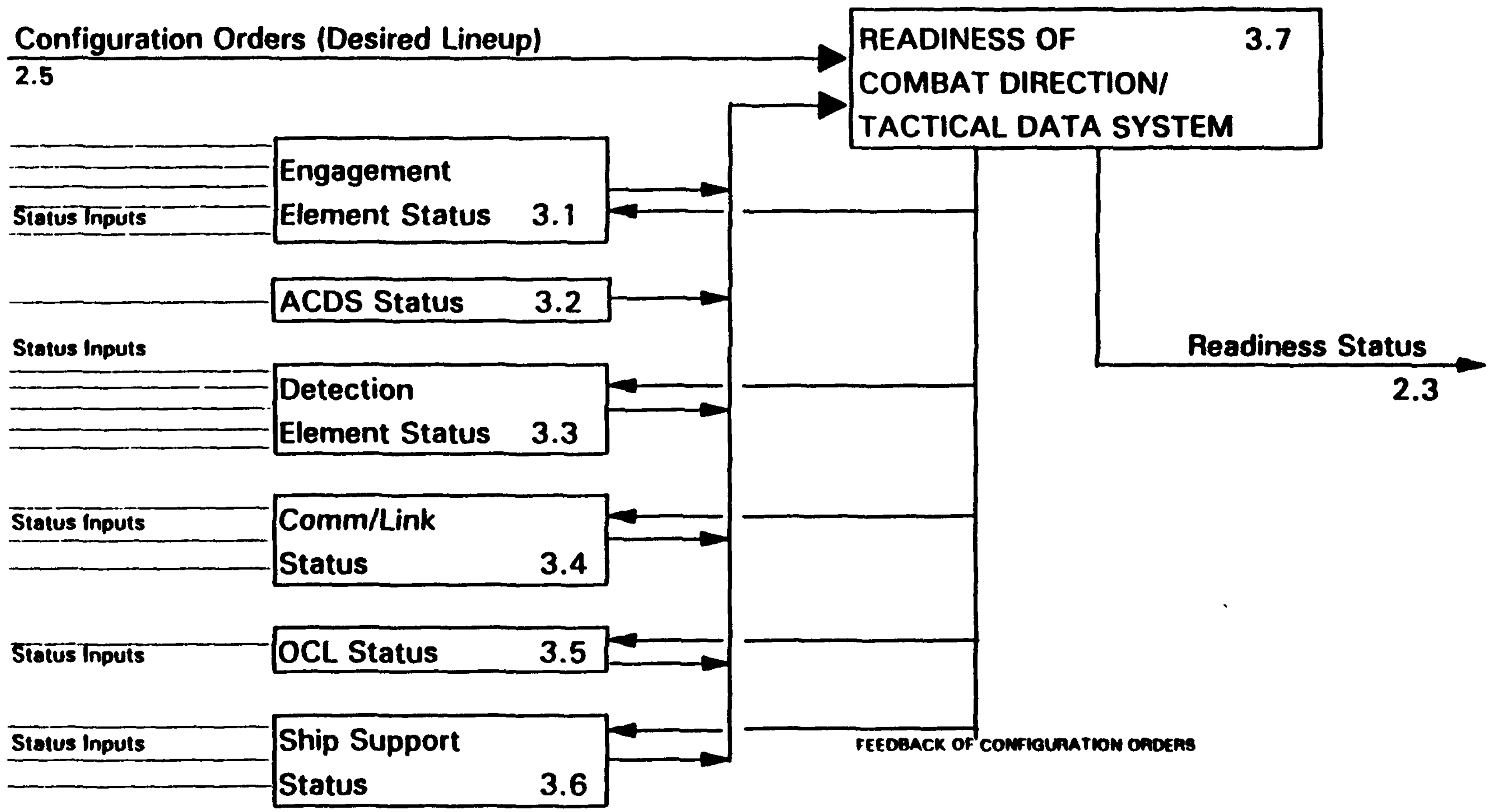


Figure 6-8d. Functional Flow Diagram (Tier 1, Block 4)

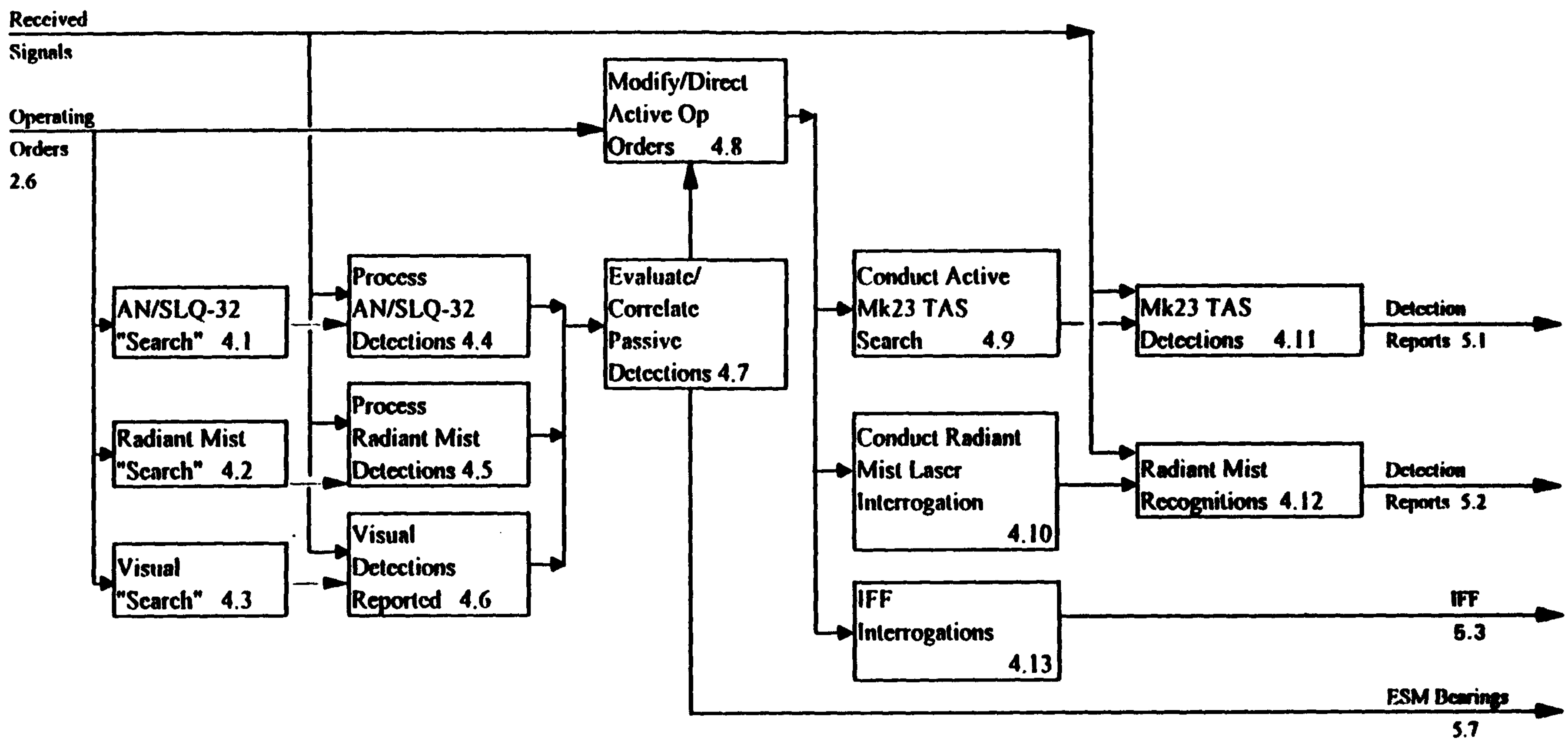


Figure 6-8e. Functional Flow Diagram (Tier 1, Block 5)

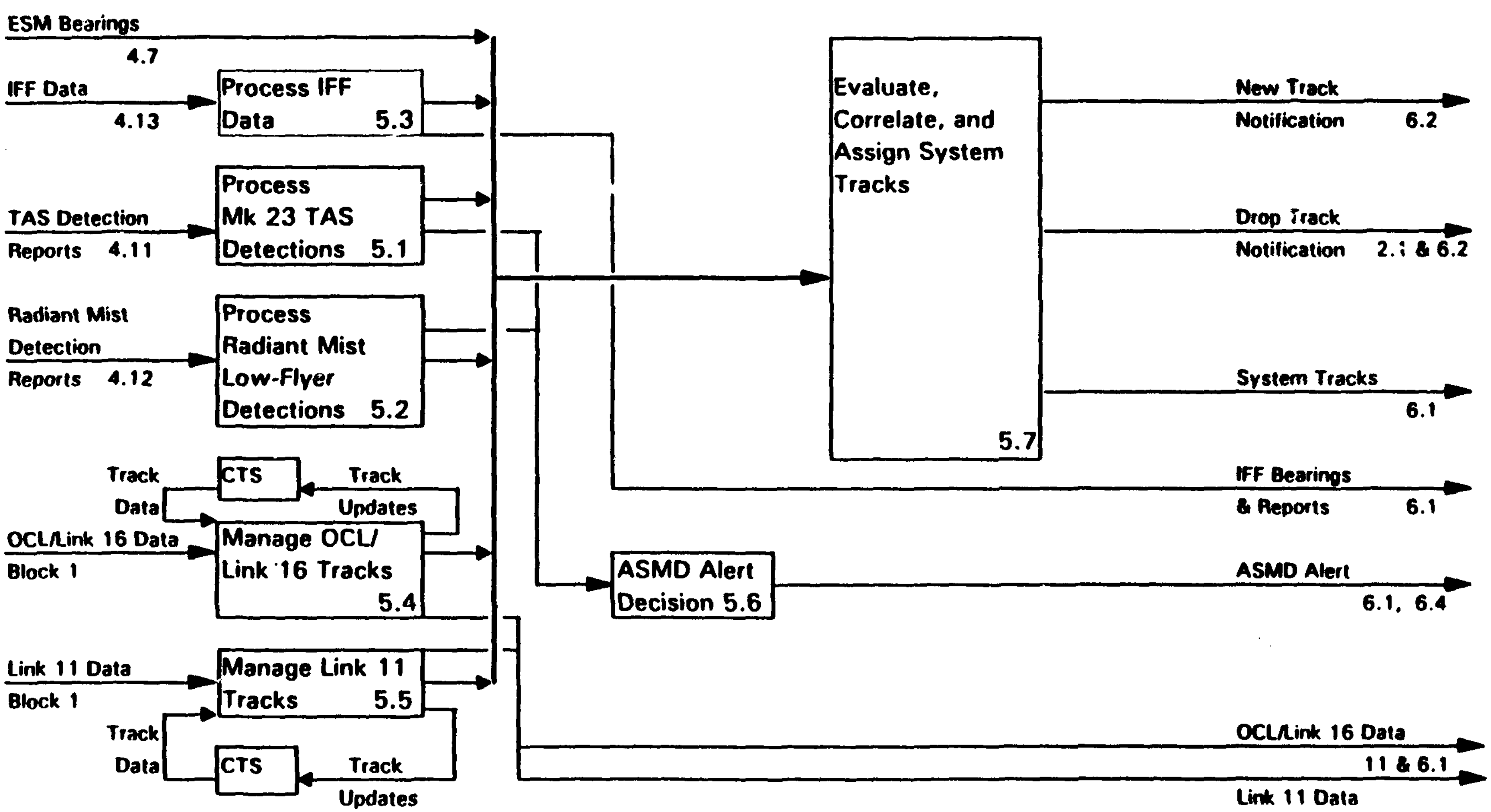


Figure 6-8f. Functional Flow Diagram (Tier 1, Block 6)

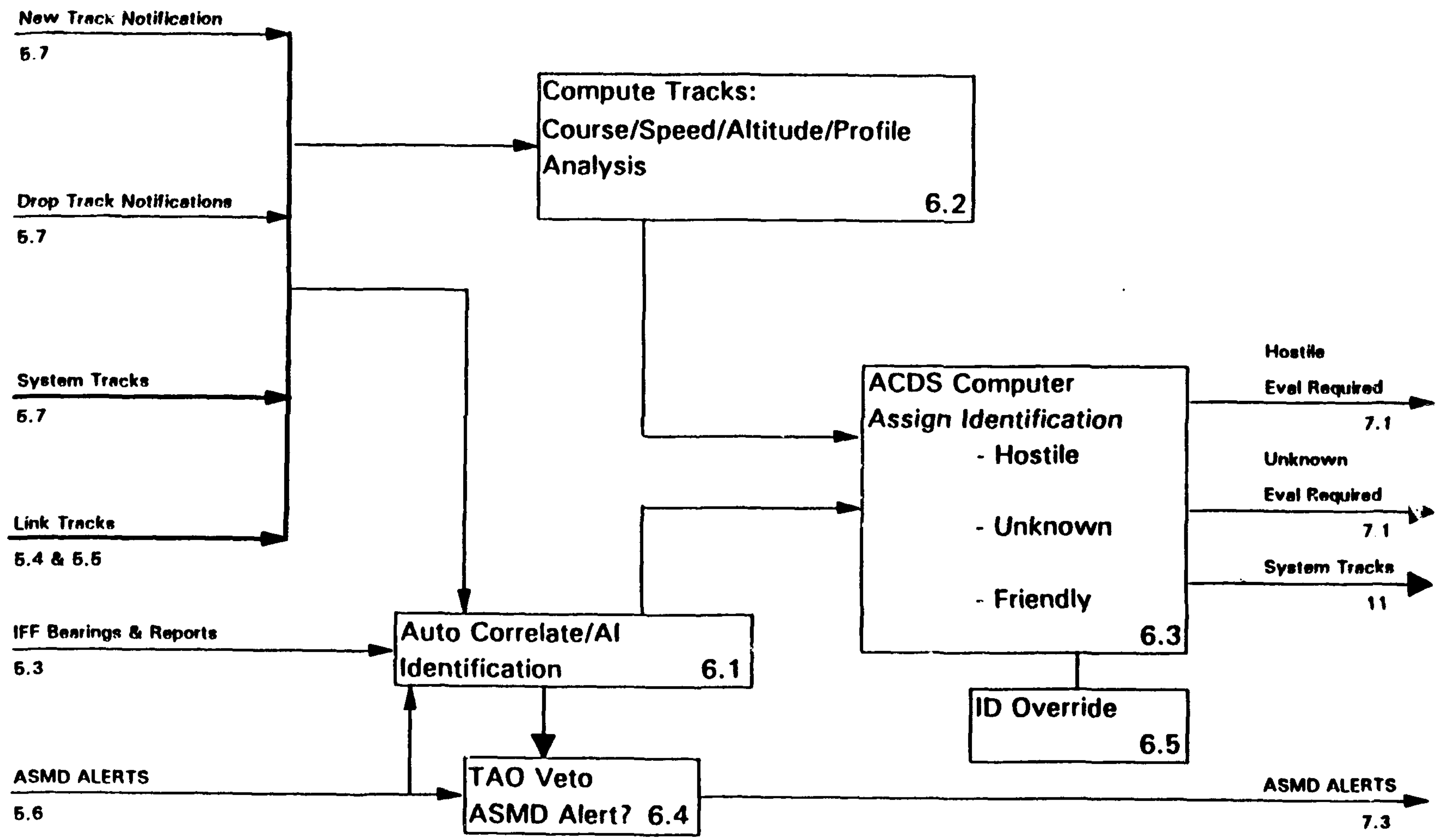


Figure 6-8g. Functional Flow Diagram (Tier 1, Block 7)

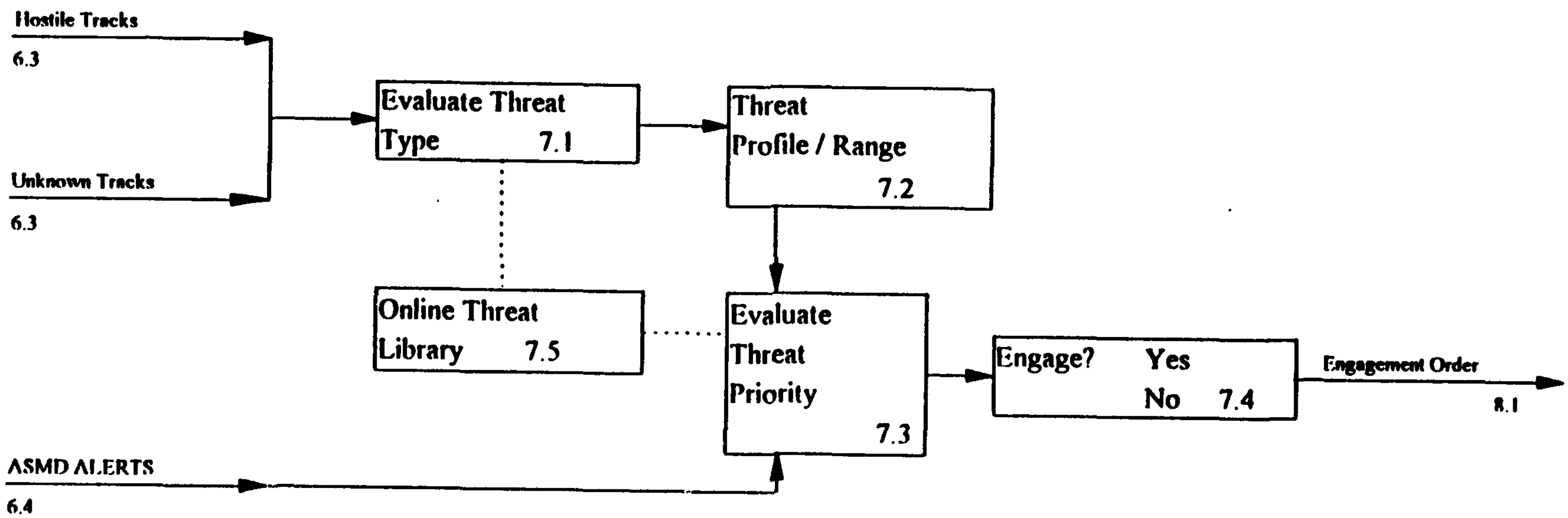


Figure 6-8h. Functional Flow Diagram (Tier 1, Block 8)

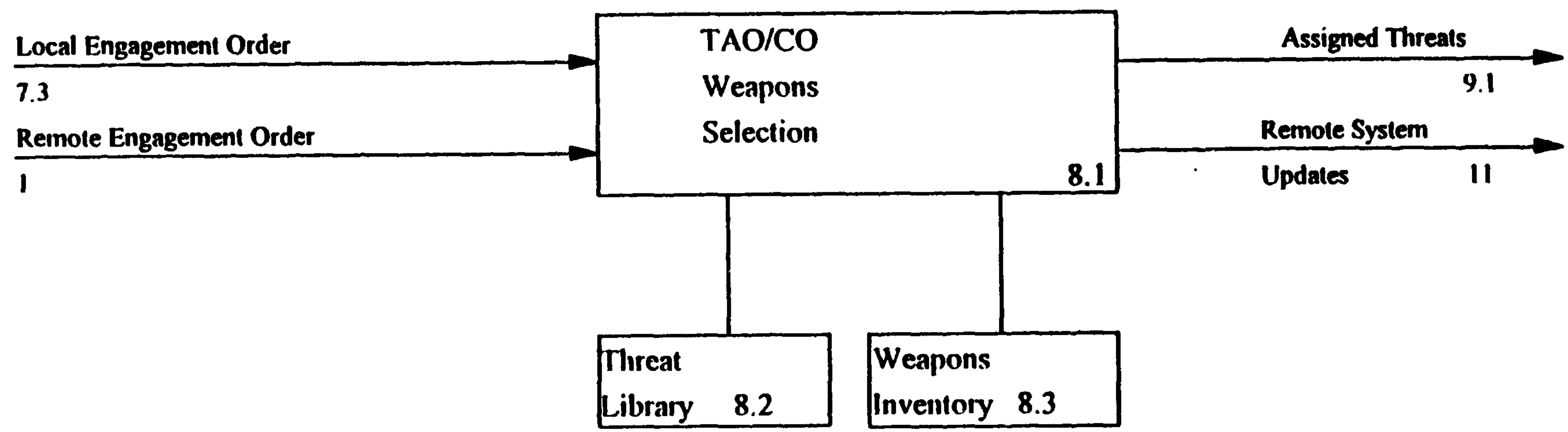


Figure 6-8i. Functional Flow Diagram (Tier 1, Block 9)

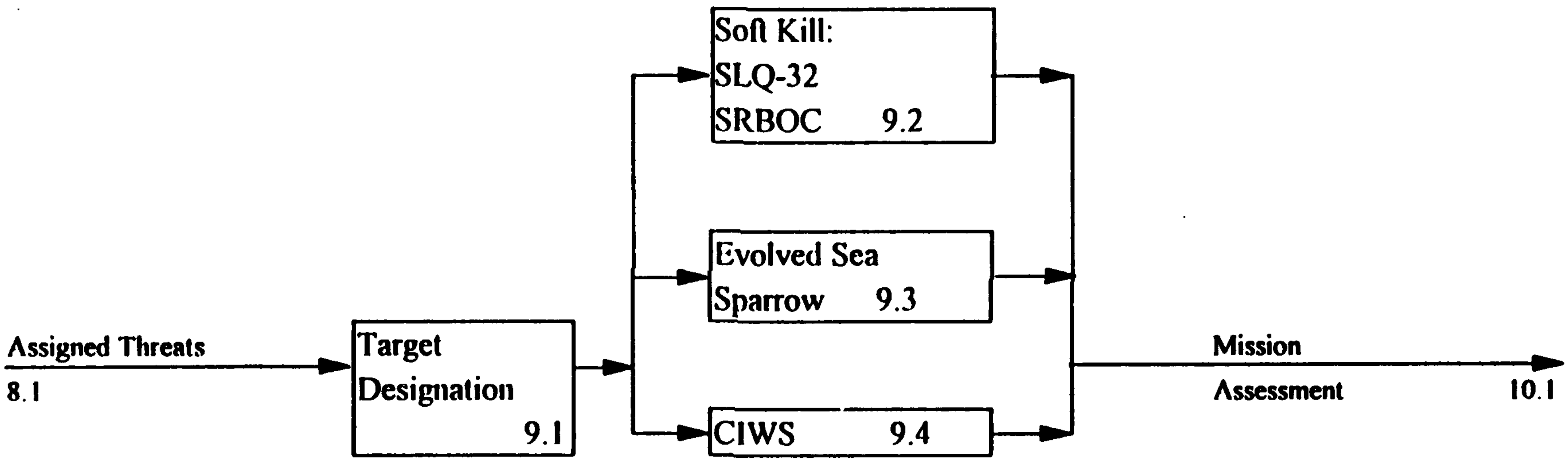


Figure 6-8j. Functional Flow Diagram (Tier 1, Block 10)

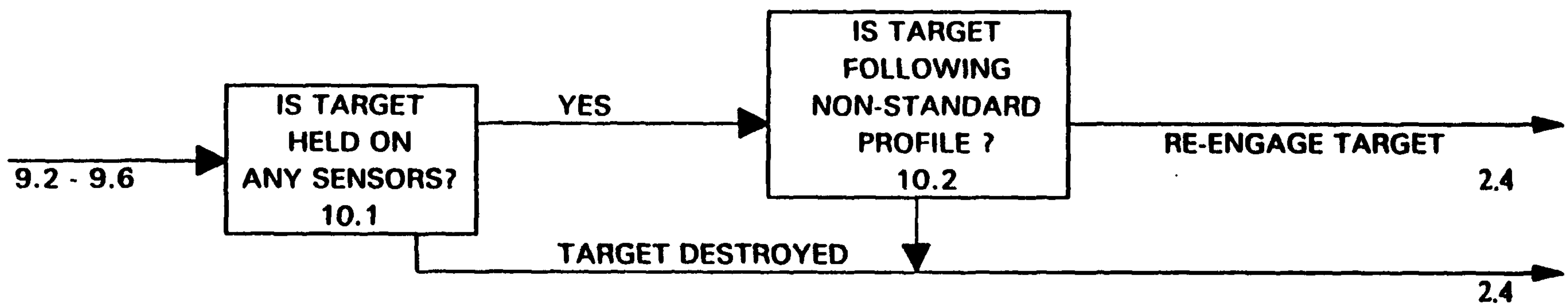
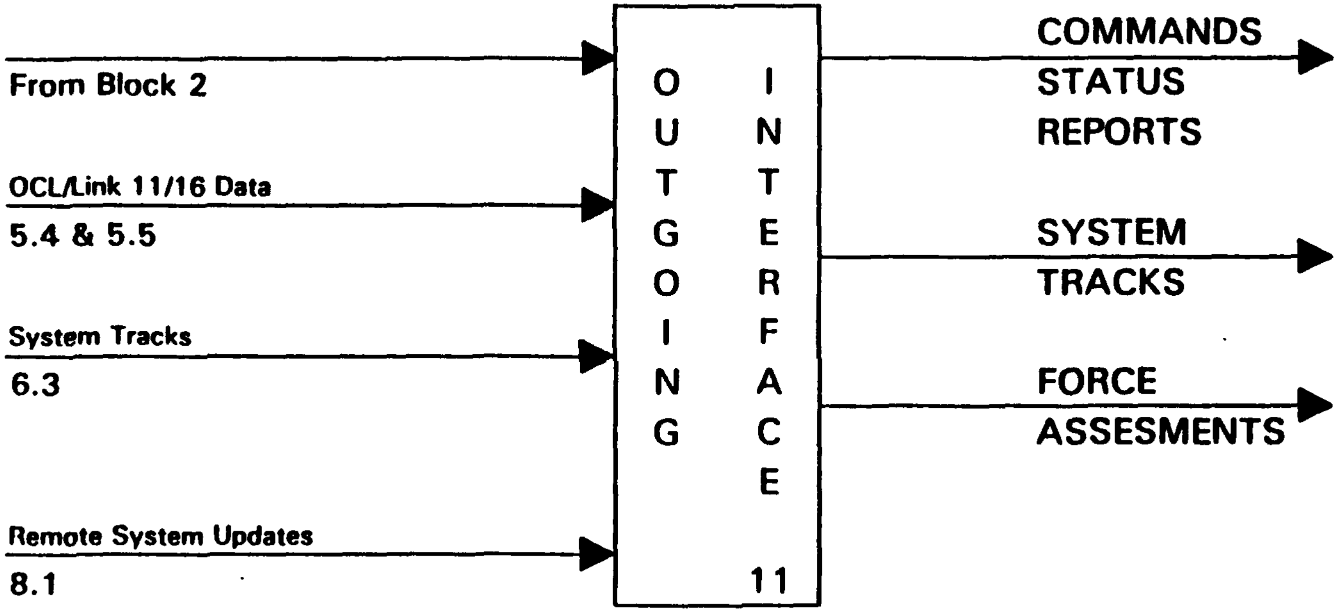


Figure 6-8k. Functional Flow Diagram (Tier 1, Block 11)



B. HULL, MECHANICAL AND ELECTRICAL

This section presents a detailed discussion of the hull, mechanical and electrical systems developed for the CMX. The Feasibility Studies (Chapter 5) identified the major components of these systems, and this section discusses how the Design Team postulated these systems may be incorporated into the CMX.

Included in the section are the propulsion and ship service electrical distribution diagrams for the CMX.

1. Engineering System Integration and Management

The Design Team postulated that Engineering Control and Monitoring Systems are connected by a redundant fiber optic network. These systems are fully integrated with the ships combat system, as discussed in the previous section. Electrical power, air conditioning and ventilation requirements, and other services would be controlled using programs based on rule-based expert systems, and aligned to provide optimum ship mission effectiveness. Graceful degradation of support services would be incorporated in the control algorithms.

Engineering control consoles would be re-configurable, self-contained, multi-function units similar in concept to the combat system multi-function consoles using a primary engineering control program (ENG/SYS-OP) and a primary engineering readiness monitoring system, (ENG/SYS-READ). Engineering control and monitoring subsystems would include:

a. AUX/SYS-OP and AUX/SYS-READ for control and monitoring of auxiliary systems;

b. DC/SYS-OP and DC/SYS-READ for control and monitoring of damage control systems;

c. EE/SYS-OP and EE/SYS-READ for control and monitoring of ships service electrical systems.

2. Hull

The CMX hull has a 10 degree flare angle which is similar to that of the DDG 51. The flare angle both improves seakeeping ability and aids in radar cross-section reduction. The CMX does not have a bow mounted sonar dome. The CMX hull incorporates a double bottom to improve survivability, strengthen the girder, and provide for tankage volume. The hull girder is composed of standard three-eighths inch medium strength steel plate, and the main deck is made from high strength HY-80 steel. The detailed midships section design is derived from the ASSET structural module (see Section C, Naval Architecture).

The weather deck is raised up to the 01 level from the aft deckhouse to the bow. From the aft deckhouse to the stern, the main deck is the weather deck. This aft weather deck section also forms the helicopter landing area and part of the aviation hangar storage area. The aviation hangar fully retracts into the aft superstructure and can be expanded aft over approximately 40% of the landing area.

3. Main Propulsion

The CMX has two main machinery rooms that contain an LM 1600-VAN2 regenerative gas turbine. Each of the two LM 1600-VAN2 gas turbines is rated at 26,400 HP and drive both a main propulsion generator, and a local propulsion derived ship service (PDSS) generator. The gas turbine and the propulsion generator are directly coupled, with each machine rated at 3600 rpm. The PDSS generator, rated at 6000 rpm, is connected to the power turbine though a gear. The gas turbine and its two associated generators are mounted on a common bedplate in the athwartships direction. This arrangement was selected to more efficiently use interior space. The Team believed that modern turbine designs were able to compensate for the additional thrust bearing loading and loading cycles due to the athwartships arrangement.

The regenerative LM 1600-VAN2 main turbines were selected primarily due to their high output power-to-weight ratio, output power-to-volume ratio, and outstanding specific fuel consumption. Regeneration improves fuel economy such that the cruising specific fuel consumption may be of the order of 0.328 lbm/hp-hr. Additionally, the LM 1600 is expected to demonstrate the high reliability of the GE marine gas turbine line which includes the venerable, reliable LM 2500.

Use of electric drive involves some technical risk to the Navy. However, in all cases of main propulsion equipment selection, commercial industrial applications currently exist. The propulsion generators incorporate liquid cooling for both the rotor and the stator. Demineralized water provides the primary local component cooling via integral tubes, sheets, or heat exchangers. The demineralized water is cooled by auxiliary seawater via an external heat exchanger. The

propulsion generators produce three phase, 6300 volt, variable frequency power to a solid state main propulsion power conditioner and frequency control system. The propulsion power conditioner incorporates silicon controlled rectifiers (SCR) in a cycloconverter arrangement. The main propulsion cycloconverter SCRs are commutated (or switched on and off) by the cyclic sinusoidal variation of the propulsion generator output. Dynamic braking load banks are used for rapid maneuvering between forward and reverse directions. And, while electronic frequency control down to zero Hertz is possible, as output frequency is reduced so is the electrical power factor (Hensler, 1989). At rated speed, the propulsion generator would operate at a relatively efficient power factor of 0.80. At near zero speed, the output power factor drops down to approximately 0.05. Electrical power factor correlates directly with efficiency; thus higher power factors are more desirable. Therefore, an optimized combination of engine speed control, propulsion frequency control, and ship speed control would need to be incorporated into the main propulsion control system. While beyond the scope of this study, such a control system with an interface of the engine control into the ship control fiber optic network is considered feasible. Current research in electric drive systems indicates that a prime mover power turbine RPM can be maintained in the range of 2400 to 3600 RPM with a feasible frequency changer and control system (Hultgren, 1992). Design specifications of such a system would be prepared prior to detailed contractor design.

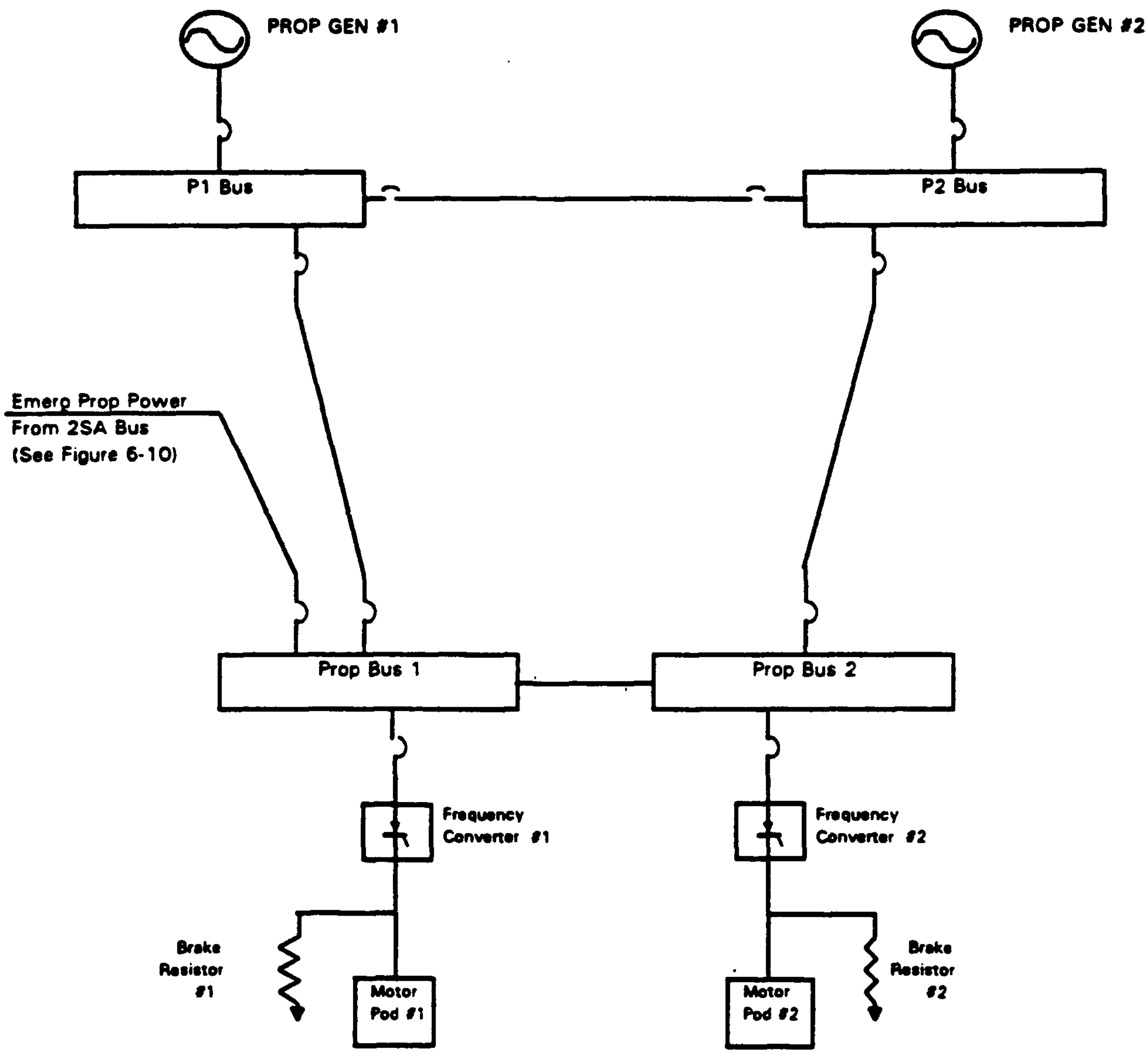
Based on the ASSET data contained in Appendix F, the propulsion generators are rated at 24.8 megawatts (MW). The propulsion switchgear would be grounded via high resistance filters to reduce potential damage to the high voltage propulsion system due to arcing ground faults. (High voltage distribution system on nuclear-powered aircraft carriers are grounded for similar

reasons.) Further, the propulsion electrical system would incorporate advanced design air-cooled circuit breakers. These air-cooled circuit breakers would be designed to minimize transient voltage harmonics which occur after typical high voltage breaker interruption operation.

The CMX uses podded propulsion motors which drive contrarotating propellers via epicyclical gears. (As noted in Chapter 5, contrarotating propellers have size, loading, and cavitation advantages over a single propeller.) A vector control system for the motor armature current and excitation field would be interfaced with the propulsion power and frequency control system. Based on the results of the ASSET Machinery module analysis, at the maximum speed of 30.3 knots, the output shaft horsepower (SHP) is 21,950 horsepower per pod. But, in a departure from the ASSET machinery module analysis, the propulsion motors would be oversized and rated at 35,000 horsepower (~26 MW) in order to ensure sufficient overload margin for relatively high speed casualty operations on a single pod. To achieve such high power in a small volume, the propulsion motors would use liquid cooling for both the rotor and the stator in the same manner as the propulsion generator. (Use of water cooling for the large main drive motors reduces the technical risk as compared to the use of supercooled drives motors that were considered in the feasibility study of the previous chapter.)

The proposed layout of the propulsion electrical system is shown on the following page.

Figure 6-9. Propulsion Electrical Distribution



4. Electrical Distribution System

The CMX uses a 450 volt, 60 Hertz (Hz) ring bus for electrical power distribution. Two propulsion derived ship service generators with variable speed constant frequency cycloconverters (VSCF) each rated at 3000 kW would normally be on-line to provide ship service power. The PDSS generators are high speed variable frequency machines and would be driven through a power takeoff gear from the main LM 1600-VAN2 turbines. The PDSS generators would have liquid cooled rotors and stators to allow for a higher power density. The variable frequency PDSS generator output power would be converted to steady and reliable 60 Hz by a solid state silicon controlled rectifier (SCR) cycloconverter system.

An Allison 501-K34 gas turbine would drive the single conventional ships service generator. This generator runs at constant speed to produce 60 Hz power and is rated at 3000 kW. Although chosen by the Team as a backup, startup, or anchor generator, this ship service gas turbine generator set could be combined with one LM 1600-VAN2/propulsion generator/PDSS generator to provide for efficient ship powering during long duration patrol operations. The SSGTG backup role actually includes two operational modes, 1) a backup for a PDSS generator and 2) an emergency backup for casualty propulsion at minimal electric service power. For case 1), the integrated power management control portion of ENG/SYS-OP would automatically start the backup SSGTG in the event of a PDSS casualty. The SSGTG would also be brought on-line during certain routine PDSS maintenance and testing conditions. For case 2), the CMX could operate at speeds up to 10 knots while providing approximately 1400 kW for ship service electrical loads.

Management of the CMX electrical distribution system would be automated by the multi-function propulsion control console computer system. This electrical power management and control system would be an embedded function of ENG/SYS-OP. System monitoring would be accomplished through the use of a fiber optic data bus as part of ENG/SYS-READ. The system monitoring data would be incorporated into a loadshed system, programmed with rule-based expert system code, which would also receive input from the combat system SYS-OP control program. In this manner, casualties and battle damage would be handled with the same "graceful degradation" as the combat systems.

The CMX does not use a separate 400 Hz distribution system. Power conversion for sensitive electronic loads would be accomplished downstream of load centers prior to the respective load through Navy Standard Electronic Power Supply Systems in accordance with MIL-STD-2306, (General Requirements *for Electronic Equipment* Specifications, 18 Jun 91).

The electrical distribution system and a block diagram of the proposed Navy Standard Electronic Power Supply are provided on a following pages.

Figure 6-10. Ship Service Electrical Distribution (Ring Bus)

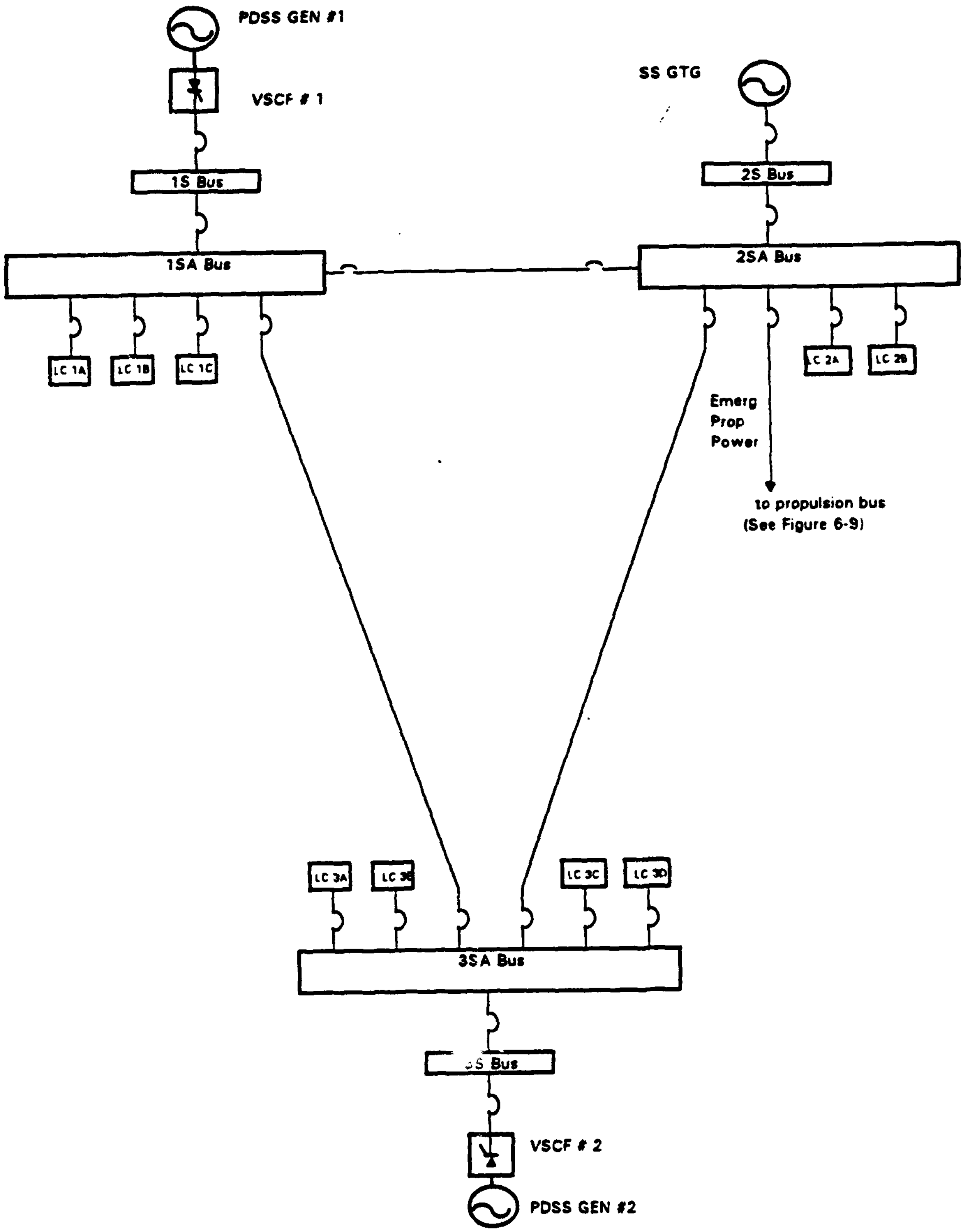
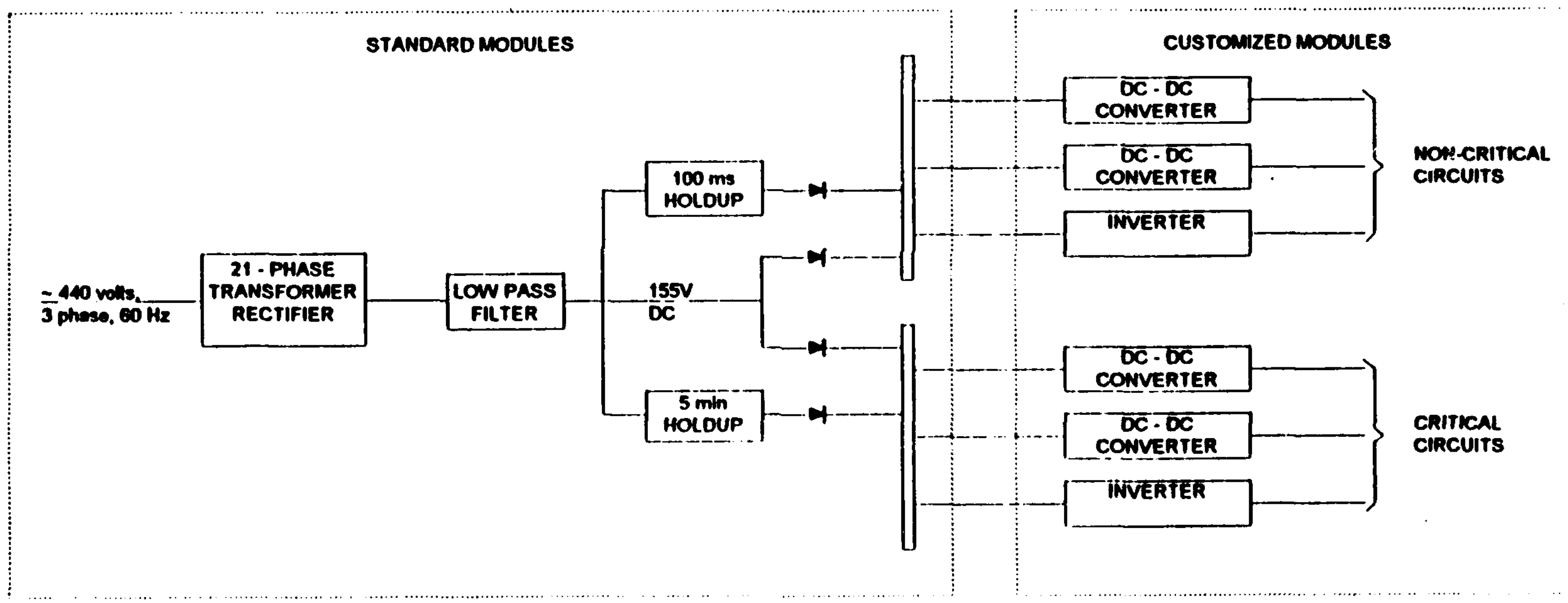


Figure 6-11. Navy Standard Electronic Power Supply



5. Auxiliary Systems

CMX auxiliaries are distributed zonally where possible. The Team decided that full implementation of zonal auxiliaries remains a long range ship design goal based on possible gains in ship impact costs (i.e., net cost reductions as a gain) and improved survivability. However, an innovative zonal auxiliary design far exceeded the time and manpower constraints of this design project.

The CMX uses six 100 ton air conditioning (AC) plants. The AC plants are distributed in three zones (forward, amidships, and aft) with a pair of 100 ton AC units in each of the zones. Use of two smaller units provides advantages by allowing more flexible in-zone lineups at low cooling loads during cold weather operations and by allowing in-zone redundancy for maintenance. The AC plants would use an advanced refrigerant similar to R-134a which meets current policy regarding potential atmospheric ozone depletion. Each AC plant would have an associated air to chill water cooling coil. Chill water would be piped for in-zone circulation with only limited inter-zone ties for use during casualties. Operation and monitoring of the AC plants and chill water system would be accomplished by the AUX/SYS-OP and AUX/SYS-READ modules in the ENG/SYS-OP and ENG/SYS-READ systems, respectively.

Two reverse osmosis (RO) water plants are installed on the CMX. The RO plants are located in the forward and aft auxiliary machinery rooms. The RO plants would provide potable water to storage tanks via an automatic brominator water treatment system. Four potable water pumps would provide water service from the storage tanks to the ship's potable water distribution system. Hot water heaters would be locally installed where required and electrically powered.

Two low capacity, medium pressure, air compressors provide ship service air. Automatic type II dehydrators would be installed in a distributed manner near local service air loads such as radar waveguides which have special low humidity or filtering requirements. Emergency starting air flasks, for all gas turbine engines, would be another primary ship service air load.

The ship's food storage refrigeration system is located in the auxiliary machinery room in the midships section below the mess facilities. Standard freeze, chill and thaw boxes would be maintained at the required temperatures. Control and monitoring of the ship's refrigeration system is accomplished through the AUX/SYS-OP and AUX/SYS-READ modules.

The CMX would have two distinct types of ventilation systems: 1) a specially filtered and monitored type used for each of two partial collective protection systems (CPS), and 2) a standard type for ventilation outside of the partial CPS zones. The CMX would incorporate higher capacity fans and a greater number of fans. Having additional fans will allow for shorter ventilation duct length from the load space to the environment as compared to a typical current ventilation system. Also, reduced CMX manning would require fewer CMX berthing spaces to be ventilated. The net effect is a reduction in wasted volume used for ventilation ducting. Ventilation system control and monitoring is accomplished through AUX/SYS-OP and AUX/SYS-READ modules with an additional interface to DC/SYS-READ and DC/SYS-OP systems.

Other necessary mechanical systems such as collection, holding and transfer (CHT), pod steering, fuel oil transfer, fuel oil service, and aviation fuel service are shown on the CMX arrangement drawings (see Section E, Arrangements).

6. Damage Control Systems

The firemain system is arranged in five zones with a total of eight fire pumps. Standard Navy titanium fire pumps rated at 1000 gallons per minute (gpm) would be installed. Each main machinery room contains one fire pump. Each of the other three zones contains two fire pumps. The fire pumps and major fireman valves would be remotely operable from Engineering Central Control. Local control panels for the three non-propulsion zones are also installed in Repair Lockers II, V, and III. Control and Monitoring would be accomplished through DC/SYS-OP and DC/SYS-READ systems.

Two partial collective protection zones would protect vital ship, combat system, and engineering control stations located in zones which roughly coincide with the ship's two deckhouses.

C. SHIP SYSTEM INTEGRATION AND MANAGEMENT

The previous sections discussed the postulated integration and management systems for the combat systems and engineering plant systems. The Design Team expects that the control and monitoring of these equipment groups would be accomplished through systems programmed with rule-based expert system code, and linked through executive level data systems called System Operating Programs (SYS-OP) and System Readiness Logic Programs (SYS-READ).

The Design Team further postulated that all ship's executive level systems would be linked on a command level through a similar data systems called Ship System Operating Program (SHIP/SYS-OP) and Ship System Readiness Logic Program (SHIP/SYS-READ).

Overall ship system control will be integrated by the SHIP/SYS-OP and SHIP/SYS-READ systems. SHIP/SYS-OP would ensure that all ship operation and support systems are aligned to effectively fight the ship in all battle conditions. Thus, for example SHIP/SYS-OP would completely integrate the control programs for the combat systems (CS/SYS-OP) and engineering systems (ENG/SYS-OP).

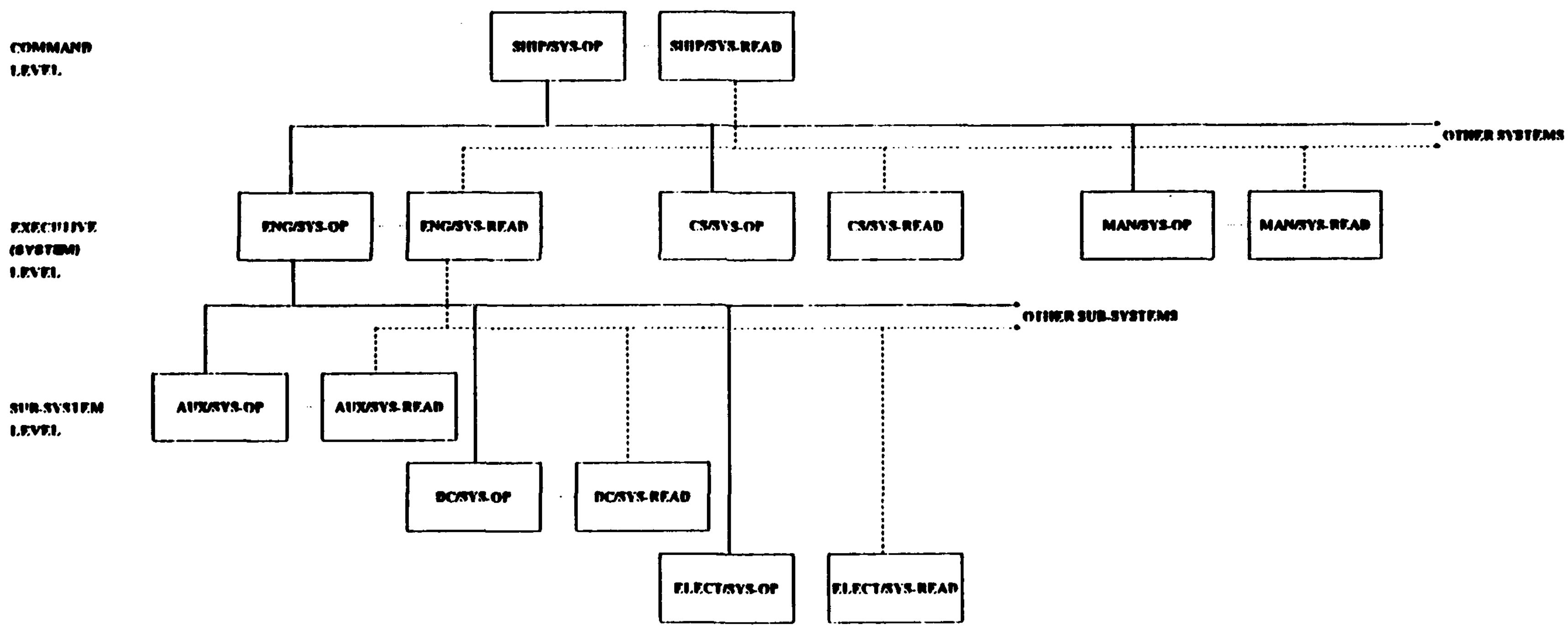
In this capacity, during an OCL missile engagement, SHIP/SYS-OP would provide command level, automated or control-by-negation commands to position the ship to fire the appropriate VLS missiles. Specific ship's speed and heading, or other configuration commands necessary to achieve the optimum firing position (based upon OCL incoming data link queries/requests channeled via CS/SYS-OP), would be transmitted to all executive level systems, such as ENG/SYS-OP or a Maneuvering System Operating Program (MAN/SYS-OP). The

commands are cued to the operators through the Standard Multi-function Console (SMC), configured for a particular system operation. Then, depending upon the CMX commanding officer's pre-programmed standing orders, the commands would be executed either manually or automatically, to realign ship systems according to the new control priorities. In-progress training modules would be switched off, or to a background standby mode. Once the commands are executed, for example electrical power, chill water and other required support systems would be aligned to provide maximum mission support.

Similarly, SHIP/SYS-READ would provide ready access to all of the ship monitoring systems incorporated in the executive level readiness logic programs (CS/SYS-READ, ENG/SYS-READ). Condition monitoring of all ship systems would be automatically recorded and stored. Thus, additional watchstanders are not required for menial logkeeping tasks. And, the ship monitoring data could be displayed by user request on any of the ship's multi-purpose consoles in either of the engineering, combat system or other control stations.

A block diagram of showing the organization of the Ship System Integration And Management, which has been detailed on the subsystem level for engineering systems, is shown on the following page.

Figure 6-12. Ship System Integration and Management



D. NAVAL ARCHITECTURE

As described in the Feasibility Study, additional ASSET analyses were done to arrive at the final synthesized CMX hull, upon which the remainder of the naval architecture analysis was performed.

The naval architecture software package, General HydroStatics (GHS), manufactured by Creative Systems, Inc., was used in conjunction with ASSET to perform the analysis. This section provides descriptions of the procedures used to evaluate the naval architecture characteristics of the CMX and presents the results. The areas analyzed include the following:

- Hull Geometry and Coefficients
- Curves of Form
- Floodable Length and Intact Stability
- Structural Report
- Weight Report

Discussion of these topics are included in the text of this section and the associated graphs are on the pages following the text.

1. Hull Geometry and Coefficients

The resulting hull parameters and coefficients are given in Table 6-1, the variation of the coefficients with ship's draft is shown in Figure 6-13, and the lines drawings of the CMX in Figure 6-14. All of the above were calculated by ASSET, and the lines drawings created with AUTOCAD® using the hull offset data produced by ASSET.

2. Curves of Form

The Displacement and Other Curves of Form as generated by GHS are shown in Figure 6-15. The reason for using the GHS software to produce these curves instead of ASSET was that ASSET does not calculate the actual trim for the ship being analyzed. Rather, it uses historical data based on previous designs. GHS, on the other hand, uses the offsets provided by ASSET and allows the user to input as precise of a load distribution as desired. From this data, it then determines trim angle and the curves of form for that trim angle. Since a fairly accurate load distribution was input to GHS for later structural analyses, it was felt that the curves produced by GHS were somewhat more accurate than those estimated by ASSET.

3. Cross Curves of Stability

The cross curves of stability provide a display of the ship's righting arm for various angles of heel over the range of likely ship displacements. For the CMX, these curves were produced using GHS and are shown in Figure 6-16.

4. Floodable Length and Intact Stability

a. Floodable Length

The floodable length curve is used to determine the allowable compartment lengths which will ensure that the margin line is not submerged should the compartments spanning the defined factor of subdivision become flooded. As described in Design Data Sheet (DDS) 079-1, *Stability and Buoyancy of Naval Surface Ships*, the factor of subdivision for combatants is 15% of the

All GHS calculations were performed using the offsets of the CMX hull produced by ASSET.

LBP and the margin line is taken to be three inches below the bulkhead deck . The standard values of permeability given in *Principles of Naval Architecture, Vol. I* (p. 190) are:

Cargo & stores	0.6
Accommodations & voids	0.95
Machinery spaces	0.85

For compartments containing VLS banks, a permeability of 0.70 was assumed.

Initially, the span of the ship between the two superstructures was divided into three compartments. The end compartments contained two VLS banks each, and the center was devoted to messing, berthing and office spaces. Using the floodable length curves produced by ASSET and superimposing the prescribed factor of subdivision upon them, the compartmentation was determined to be inadequate just aft of amidships. That is, to meet the floodable length criteria, the permeability in the center compartment needed to be less than 0.80, and this was unlikely based on the intended use for this compartment. Therefore, an additional watertight bulkhead was placed in each of these three compartments, allowing the CMX to meet the floodable length criteria. This result is shown in Figure 6-17. Also, the calculation of the V-lines for the transverse bulkheads was not performed because the CMX does not have non-watertight penetrations below the bulkhead deck. Unlike most combatants, there is no need for access at this point because passage is blocked at nearly every bulkhead by the VLS banks or engine ducting.

b. Intact Stability

Intact stability analysis was performed by ASSET for beam winds and high speed turns. As shown in Figure 6-18, the CMX meets all of the criteria described in DDS 079-1 for stability with 100 knot beam winds. For the case of high speed turns, the CMX heeling angle of 21°

exceeded the maximum specified of 15°. The main reason for this is the high maximum speed of the CMX and—although not accounted for by ASSET—this excess would likely be amplified by the increased maneuverability of podded propulsion. Although the reason for this criterion is not one of survivability but of crew comfort, it was decided to install a "rudder angle limiter" which would gradually limit the maximum rudder angle allowed as ship speed increased above 22 knots. The Design Team envisioned that this automatically engaged device, could also be quickly overridden at the discretion of the Officer of the Deck. Figure 6-19 shows the intact turning stability for high speed turns. This figure assumes the rudder angle limiter is engaged and meets all of the criteria specified in DDS 079-1.

5. Structural Report

The structural design of the ship is largely dependent on the longitudinal load distribution along the hull girder. ASSET uses historical data based on the hogging and sagging bending moment of 13 previous ship designs, and the current ship's section modulus to calculate the primary stresses. These stresses are then used to calculate the midship section scantlings for the component materials specified. Thus, the midship section of the CMX shown in Figure 6-20 is only remotely related to the actual stresses seen at this station. Although more accurate load distribution data cannot be input into ASSET, it can be used by GHS to produce more precise bending moment diagrams. The procedure used to do so was as follows:

a. Using the weight tables provided by ASSET and the rough ship layout determined by the team, the loads were divided into three groups:

(1) local loads which could be assigned specific locations;

(2) distributed loads related to the hull structure;

(3) other distributed loads.

b. The local loads were assigned specific points or local distribution ranges along the hull, as applicable. For example, a CIWS mount was assumed to exist at a point, while a main engine and its support systems was assumed to be uniformly distributed over a range of about 20 feet centered about their estimated position in the ship. These calculations are shown in Table 6-2.

c. To determine the distribution of the hull structure load, the hull sectional area curve was added to a curve representing the cross-sectional area of the inner bottom (it was felt that the structure making up the inner bottom was too significant to be ignored when calculating the distribution of the hull structure load). The resulting curve was normalized and the total structural weight distributed using this curve and Simpson's Rule (see Table 6-3 and Figure 6-21).

d. In a similar manner, the remaining loads were distributed as a function of the hull sectional area curve alone. This was felt to be appropriate since the distribution of these loads is closely related to that of the volume of the hull. The calculations are shown in Table 6-3, and the curve in Figure 6-21.

After the total load distribution was calculated, it was input to GHS and the bending moment curves calculated for hogging and sagging under the influence of a trochoidal wave. The results are shown in Figures 6-22 and 6-23 for hogging and sagging, respectively.

6. Weight Report

The loads which were used above to determine the load distribution were calculated by ASSET and are shown in Appendix F. Most of the items associated with the combat systems—in addition to the turbine generators, main engines, drive train, superstructure parameters, and hull materials—were specified by the Design Team early during the Feasibility Studies.

Table 6-1. CMX Hull Geometry & Characteristics

Δ_{LS} (LT)	6,550
Δ_{FL} (LT)	8,420
LBP (ft)	578
LOA (ft)	607
BEAM @ DWL (ft)	57.2
BEAM @ Weather Deck	65.6
DEPTH @ STA 10 (ft)	43.1
DRAFT @ DWL (ft)	19.1
Hull Volume (ft^3)	1.03×10^6
Superstructure Volume (ft^3)	1.16×10^5
C_P	0.56
C_X	0.82
C_{WP}	0.76
BM_T (ft)	17.7
GM_T (ft)	2.86
GM_L (ft)	1,659
KG (ft)	26.5
LCB/LCP	0.51
Waterplane Area (ft^2)	25,170
Wetted Surface (ft^2)	33,930

Figure 6-13. Hull Coefficients

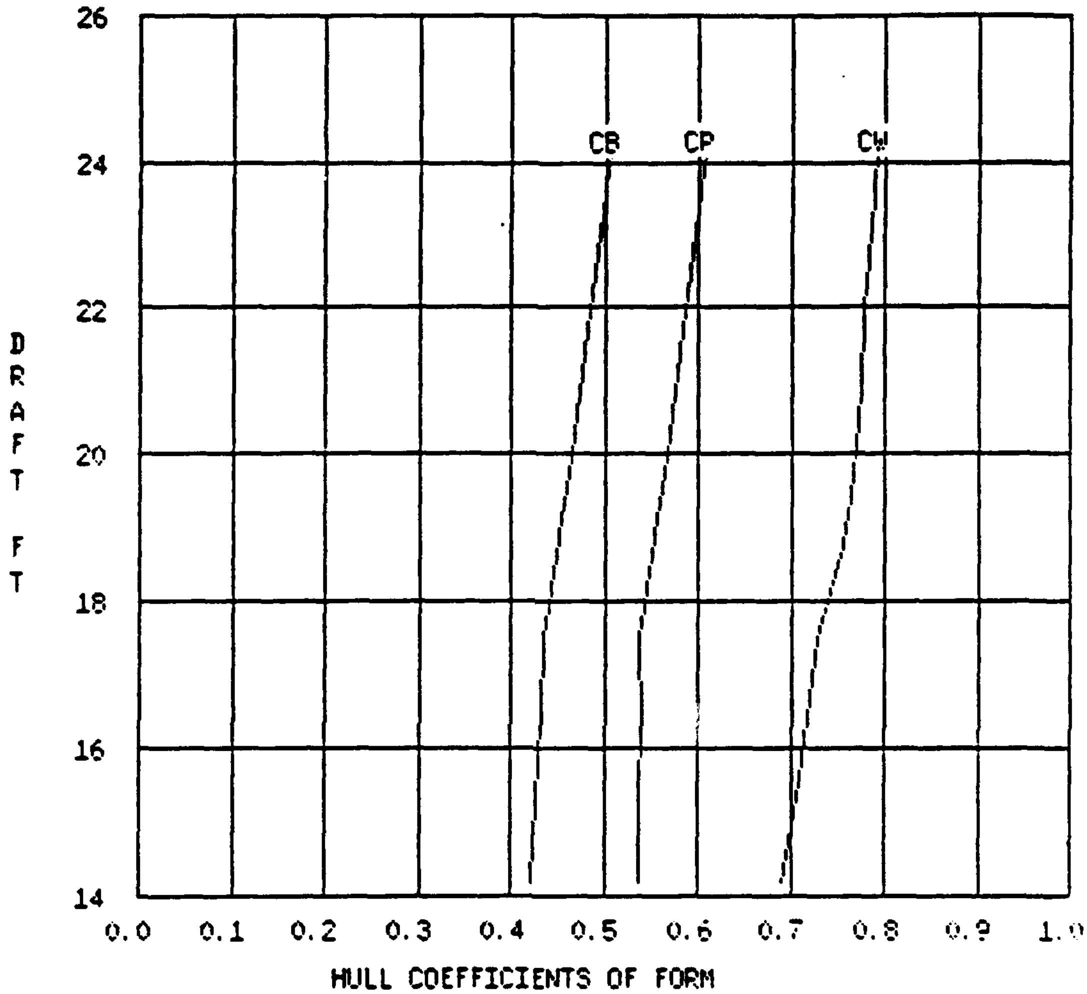
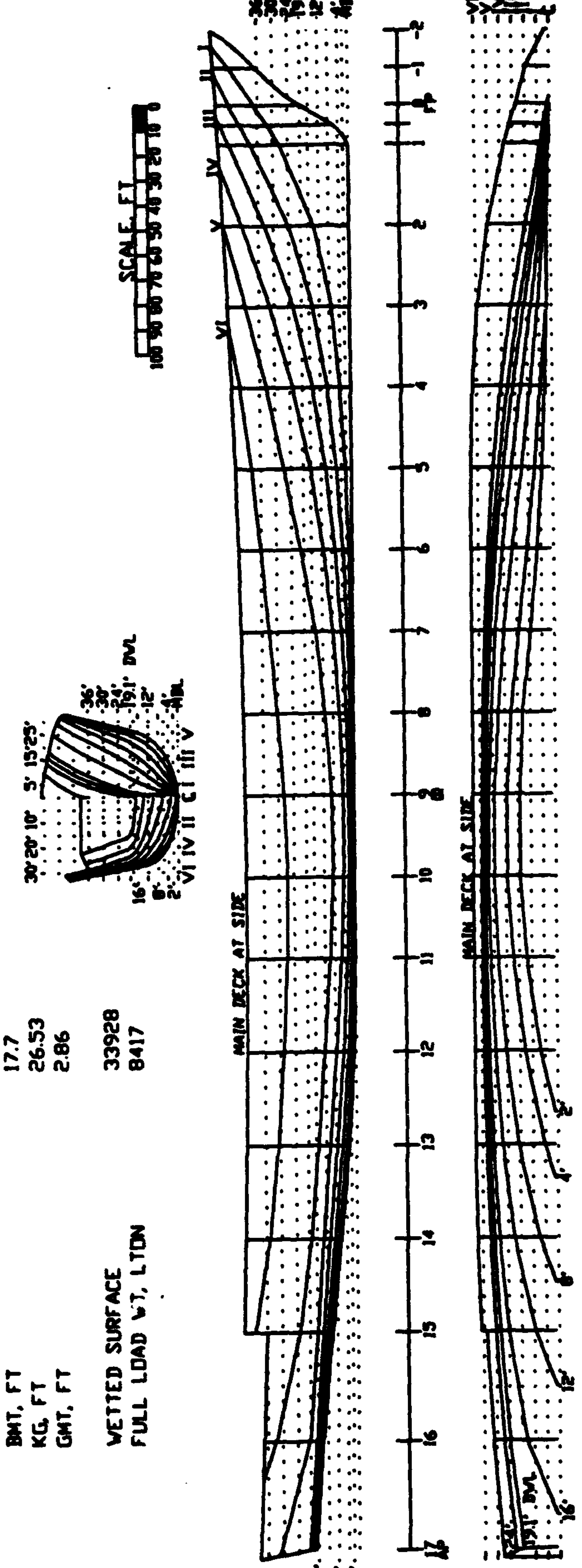


Figure 6-14. Lines Drawing



HULL CHARACTERISTICS

LBP,FT	577.7
LOA, FT	607.4
BEAM, FT	57.2
BEAM @ WEATHER DECK, FT	65.6
DRAFT, FT	19.1
PRISMATIC COEF	0.559
MAX SECTION COEF	0.818
WATERPLANE COEF	0.763
LCB/LCP	0.506
KB, FT	11.79
BMT, FT	17.7
KG, FT	26.53
GMT, FT	2.86
WETTED SURFACE	33928
FULL LOAD WT, LTON	8417

Figure 6-15. Curves of Form

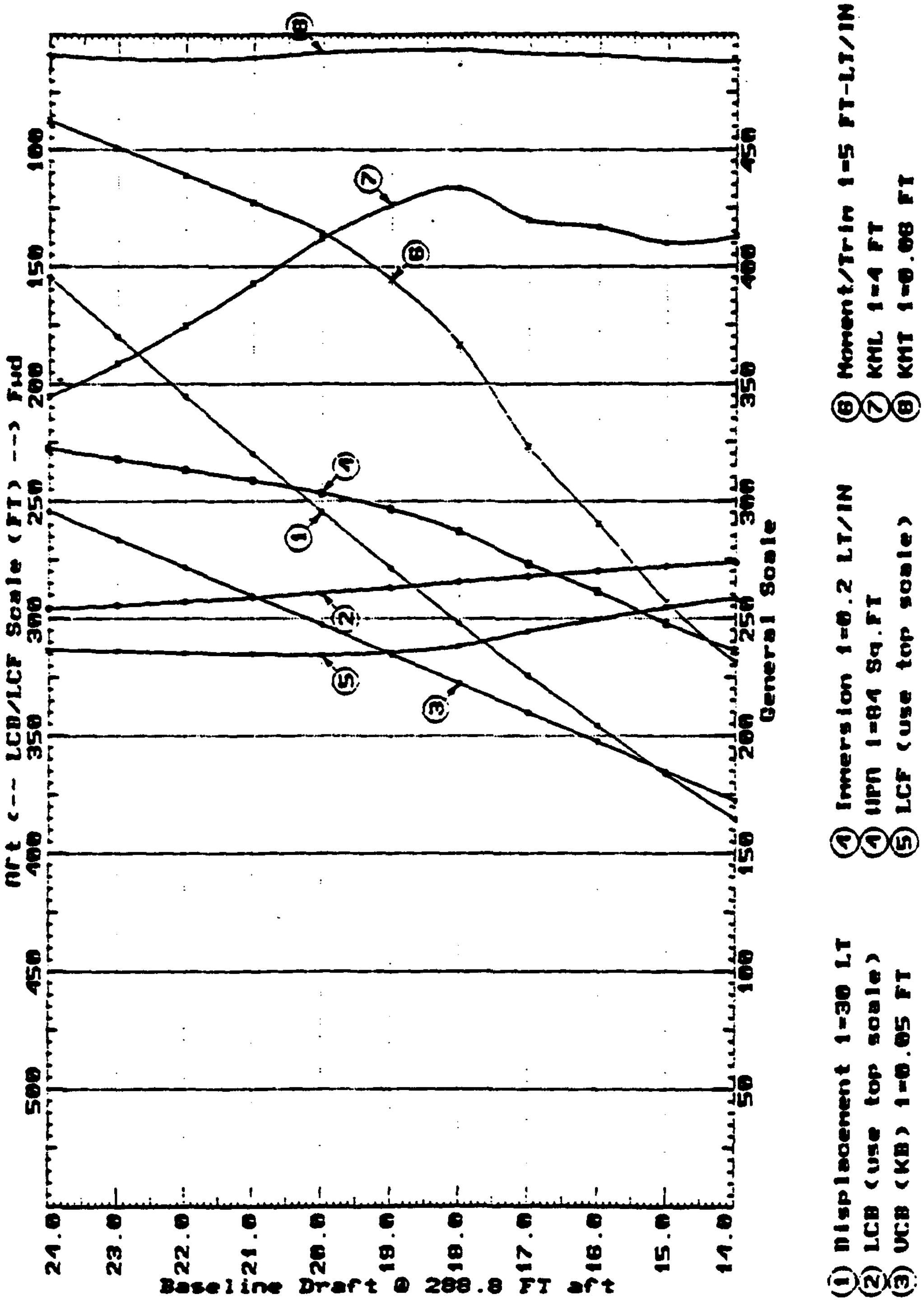


Figure 6-16. Cross Curves of Stability

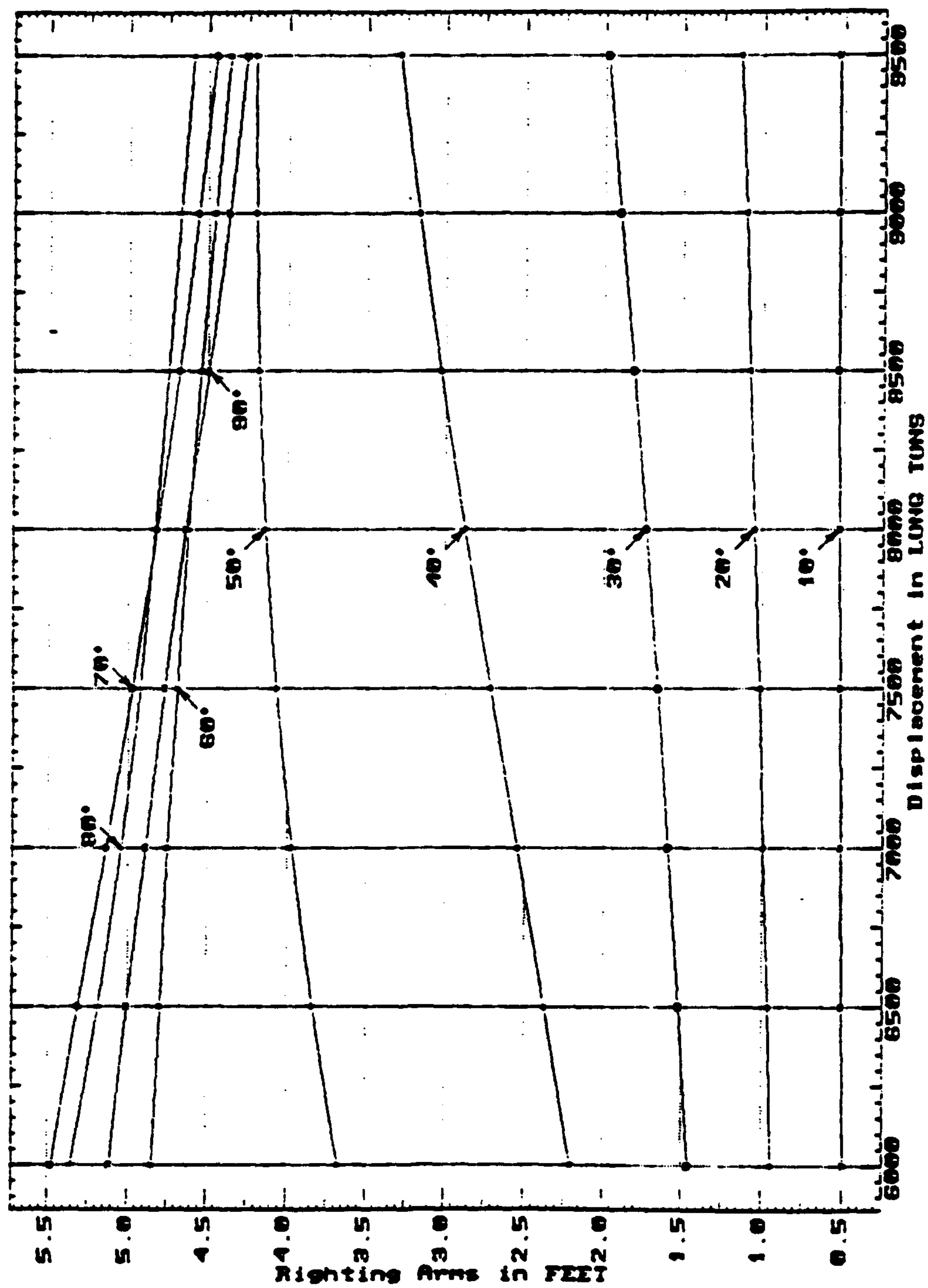


Figure 6-17. Floodable Length Curve

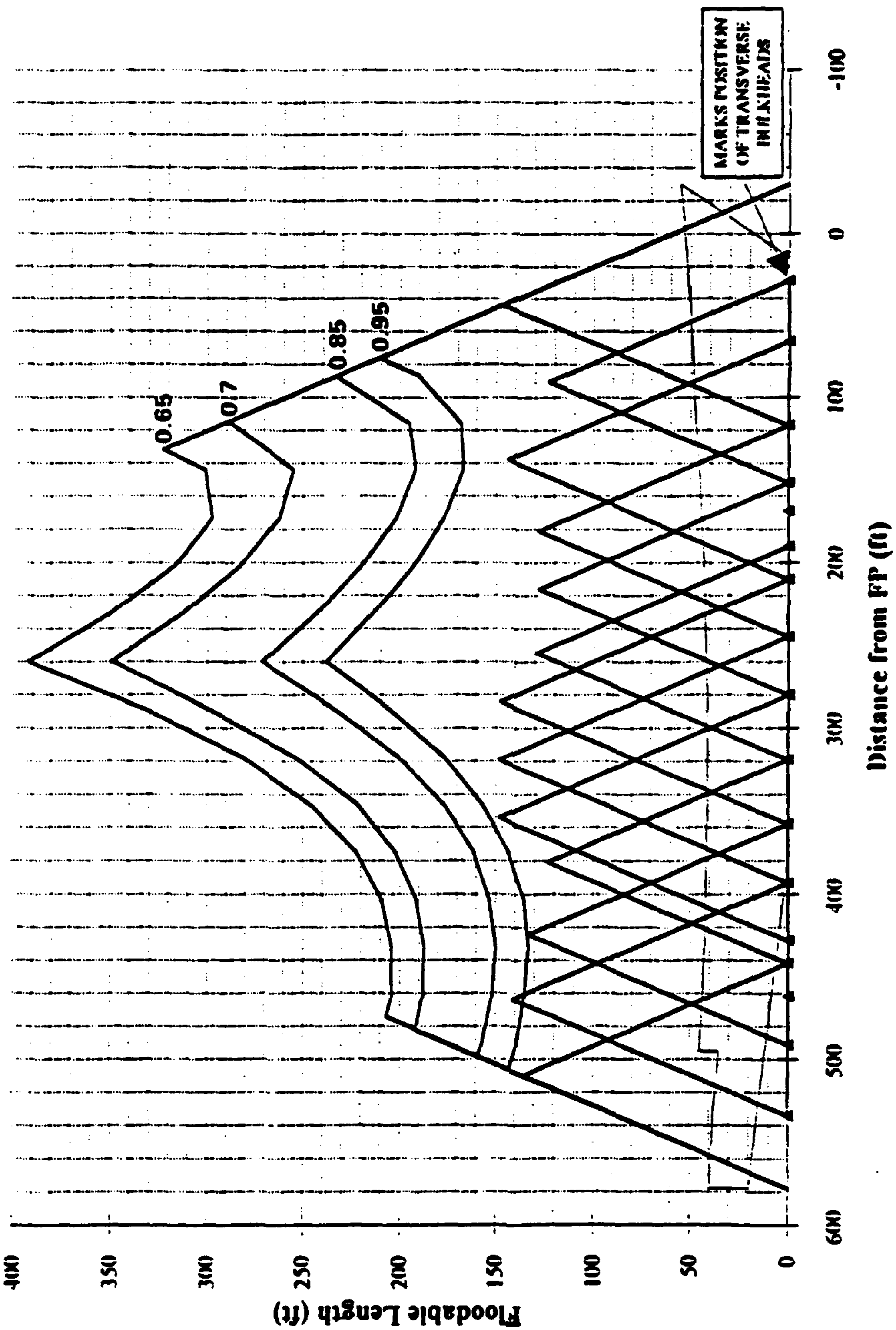


Figure 6-18. Intact Beam Wind Stability Curve

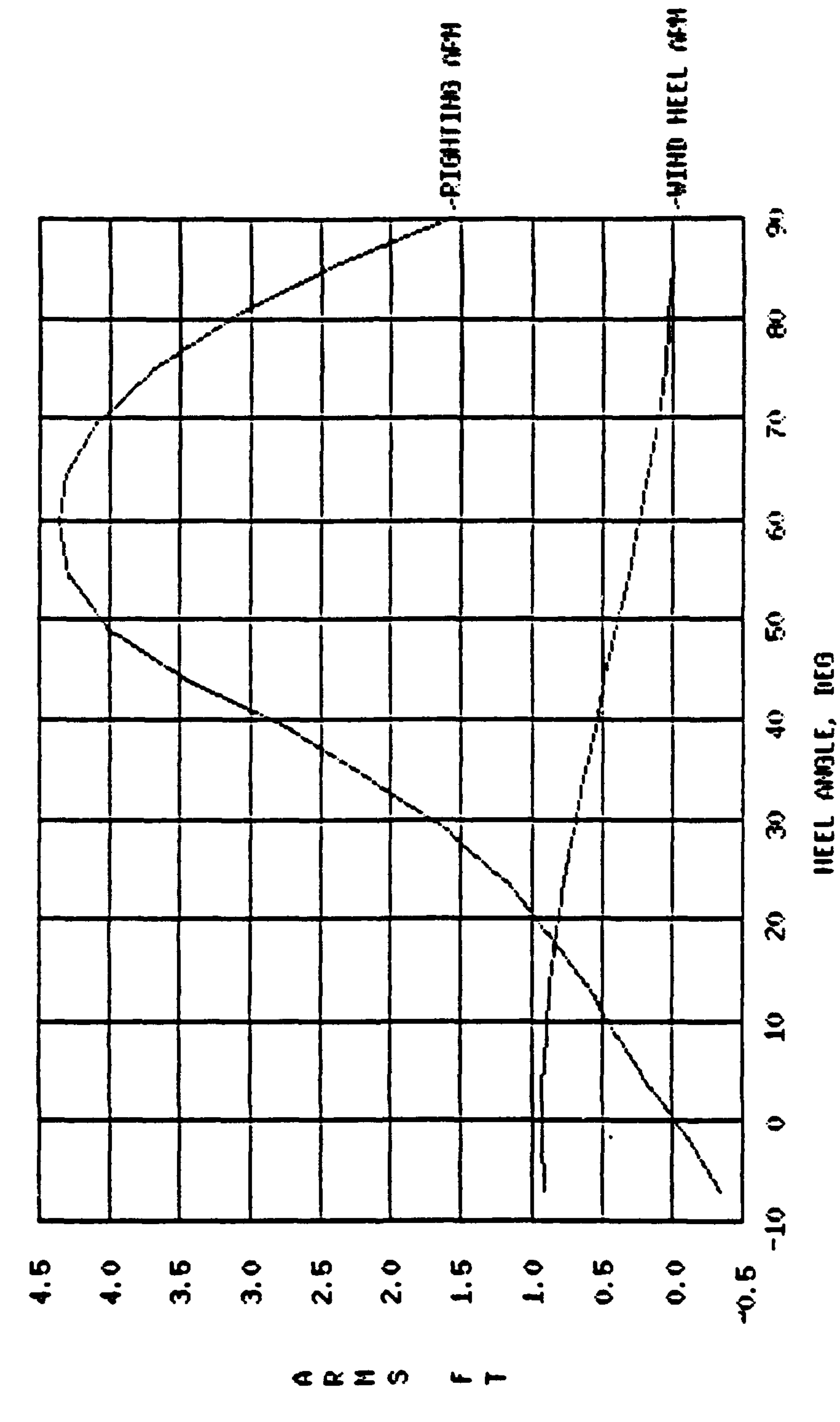


Figure 6-19. Intact Turning Stability Curve

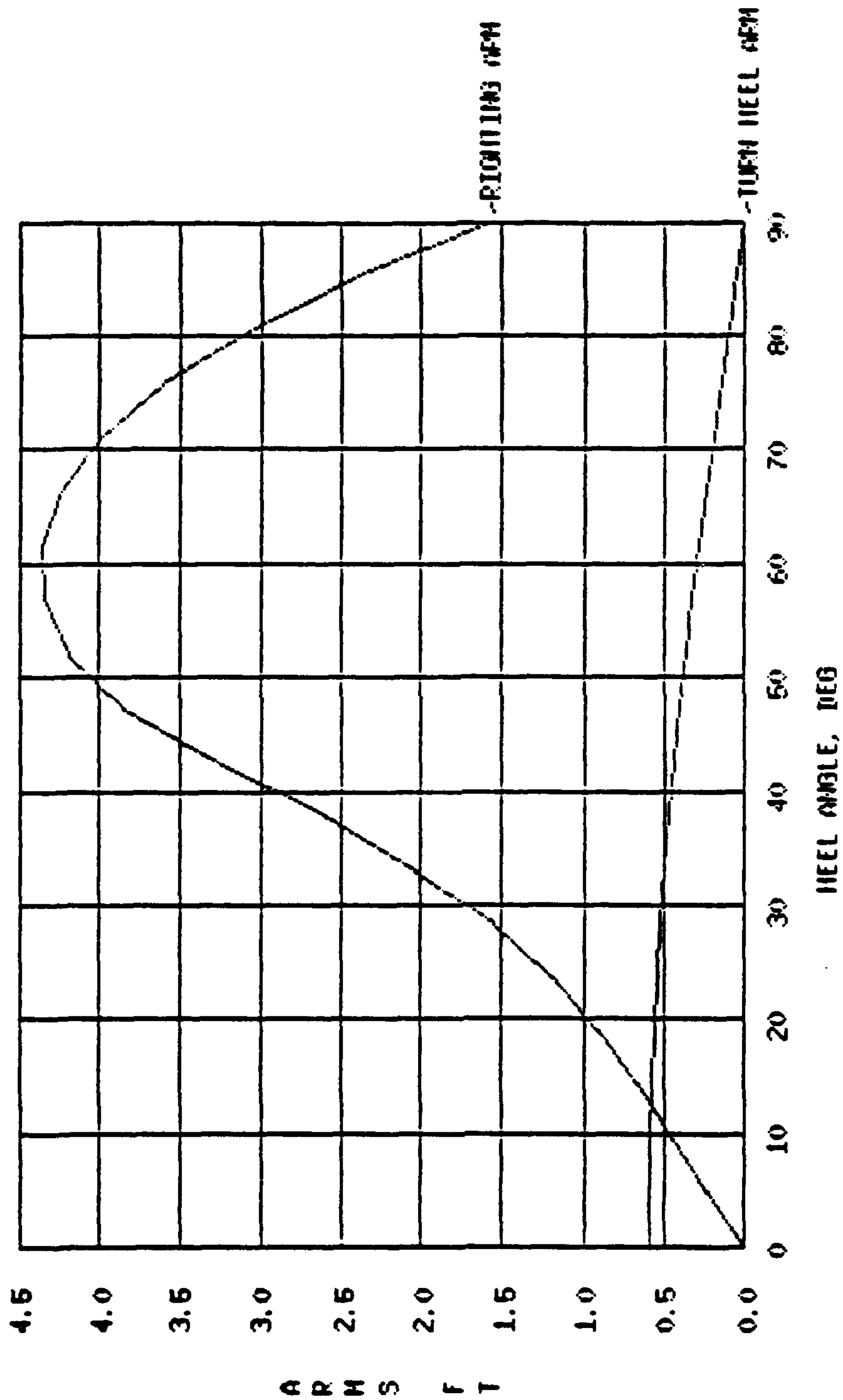


Figure 6-20. Midship Section

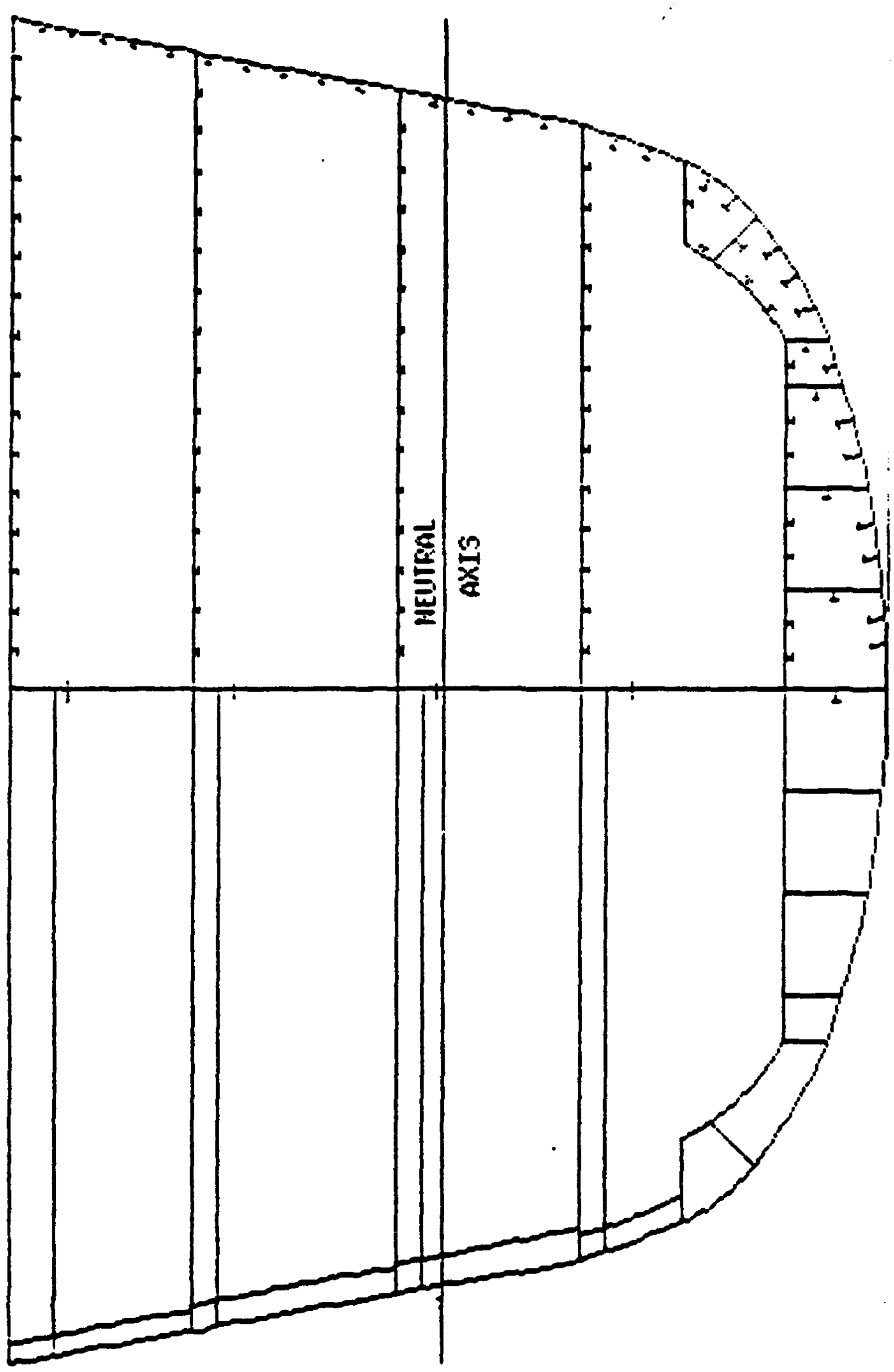


Table 6-2. Local Load Calculations

SWBS Group	Component	Load (LT)	Distance from FP to fwd end of load (ft)	Distance from FP to aft end of load (ft)	Load Distribution (LT/ft)	VCG (ft)
110	Landing Pad	10.7	501.06	578.00	0.14	16
150	Fwd Deckhouse	128.58	152.00	210.00	2.22	56.77
150	Aft Deckhouse	94.52	427.00	491.00	1.48	53.73
200	Fwd Propulsion	196.65	194.68	213.83	10.27	19.54
200	Aft Propulsion	196.65	450.00	469.15	10.27	19.54
310, 340	Sep SS GTG	28.33	156.38	169.15	2.22	21.84
310, 340	Fwd VSCF Gen	14.93	194.68	204.26	1.56	21.84
310, 340	Aft VSCF Gen	14.93	450.00	459.57	1.56	21.84
410, 420, 440, 450, 470	CIC	97.00	169.15	191.49	4.34	40.90
410, 420, 440, 450, 470	ACIC	2.90	430.85	443.62	0.23	45.92
710	Fwd CIWS	6.60	162.77	162.77	n/a	69.31
710	Aft CIWS	6.60	488.30	488.30	n/a	69.31
720	VLS Bank #1	74.50	68.62	98.94	2.46	32.16
720	VLS Bank #2	74.50	98.94	114.89	4.67	32.16
720	VLS Bank #3	149.00	118.09	148.40	4.91	32.16
720	VLS Bank #4	149.00	215.43	245.74	4.91	32.16
720	VLS Bank #5	149.00	248.94	279.26	4.91	32.16
720	VLS Bank #6	149.00	362.23	392.55	4.91	32.16
720	VLS Bank #7	149.00	395.74	426.06	4.91	32.16
780	Helo Weapons	2.70	481.91	481.91	n/a	50.27

Total (LT) 1695.10

Table 6-3. Total Distributed Load

Longitudinal Length (ft)	(1) Hull Sectional Area (ft^2)	(2) Inner Bottom Sectional Area (ft^2)	(1) + (2) Total Sectional Area (ft^2)	Trapezoidal Multip Factor	Function of Hull Area	Function of Total Area	Normalized Hull Sectional Area	Normalized Total Sectional Area	Load Dist for Group 100* (LT/ft)	Load Dist For Remaining Dist Loads** (LT/ft)	TOTAL DIST LOAD (LT/ft)
0	0	0	0	0.5	0	0	0.00E+00	0.00E+00	0.000	0.000	0.000
29	80	25	105	1	80	105	2.77E-04	2.89E-04	0.914	0.983	1.898
58	170	35	205	1	170	205	5.88E-04	5.63E-04	1.785	2.089	3.874
87	280	55	335	1	280	335	9.69E-04	9.21E-04	2.917	3.441	6.358
116	390	70	460	1	390	460	1.35E-03	1.26E-03	4.006	4.793	8.799
145	500	90	590	1	500	590	1.73E-03	1.62E-03	5.138	6.144	11.282
173	610	195	805	1	610	805	2.11E-03	2.21E-03	7.010	7.496	14.507
202	710	230	940	1	710	940	2.46E-03	2.58E-03	8.186	8.725	16.911
231	800	265	1065	1	800	1065	2.77E-03	2.93E-03	9.275	9.831	19.106
260	860	280	1140	1	860	1140	2.98E-03	3.13E-03	9.928	10.568	20.496
289	890	280	1170	1	890	1170	3.08E-03	3.22E-03	10.189	10.937	21.126
318	880	280	1160	1	880	1160	3.05E-03	3.19E-03	10.102	10.814	20.916
347	840	280	1120	1	840	1120	2.91E-03	3.08E-03	9.754	10.323	20.076
376	760	265	1025	1	760	1025	2.63E-03	2.82E-03	8.926	9.340	18.266
405	660	230	890	1	660	890	2.28E-03	2.45E-03	7.751	8.111	15.861
434	520	0	520	1	520	520	1.80E-03	1.43E-03	4.528	6.390	10.919
462	410	0	410	1	410	410	1.42E-03	1.13E-03	3.570	5.038	8.609
491	280	0	280	1	280	280	9.69E-04	7.70E-04	2.438	3.441	5.879
520	190	0	190	1	190	190	6.57E-04	5.22E-04	1.655	2.335	3.990
549	110	0	110	1	110	110	3.81E-04	3.02E-04	0.958	1.352	2.310
578	50	0	50	0.5	25	25	1.73E-04	1.37E-04	0.435	0.614	1.050

Hull Vol. (ft^3) 288985

Total Vol. (ft^3) 363805

* Group 100, not including part of group 110 (Landing Pad) and all of group 150 (Deckhouses): 3168.2 LT

** Groups 320, 330, 390, 430, 480, 490, 500, 600, and F00: 3551.3 LT

Figure 6-21. Normalized Load Distribution Curves

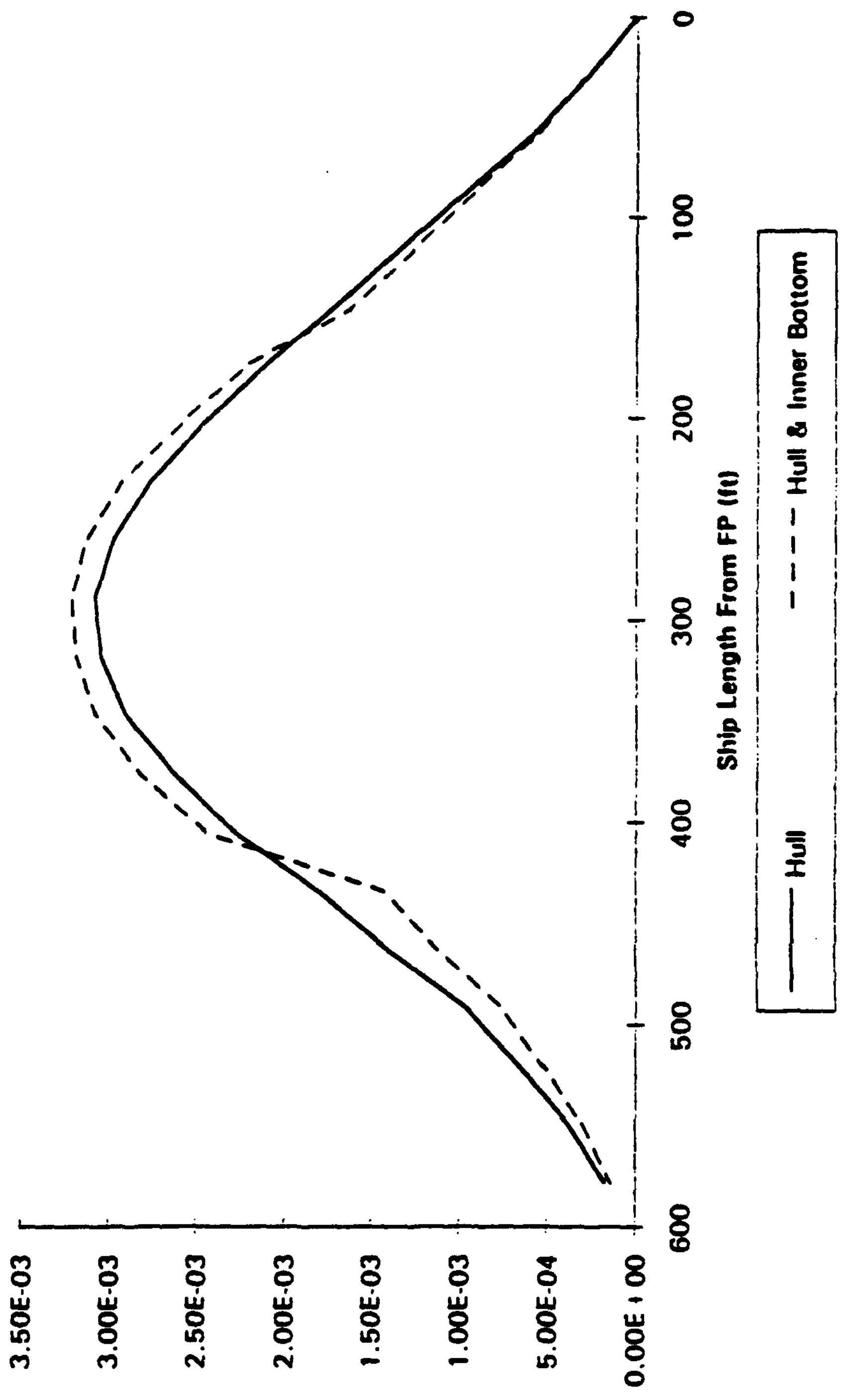


Figure 6-22. Bending Moment Curve (Hogging)

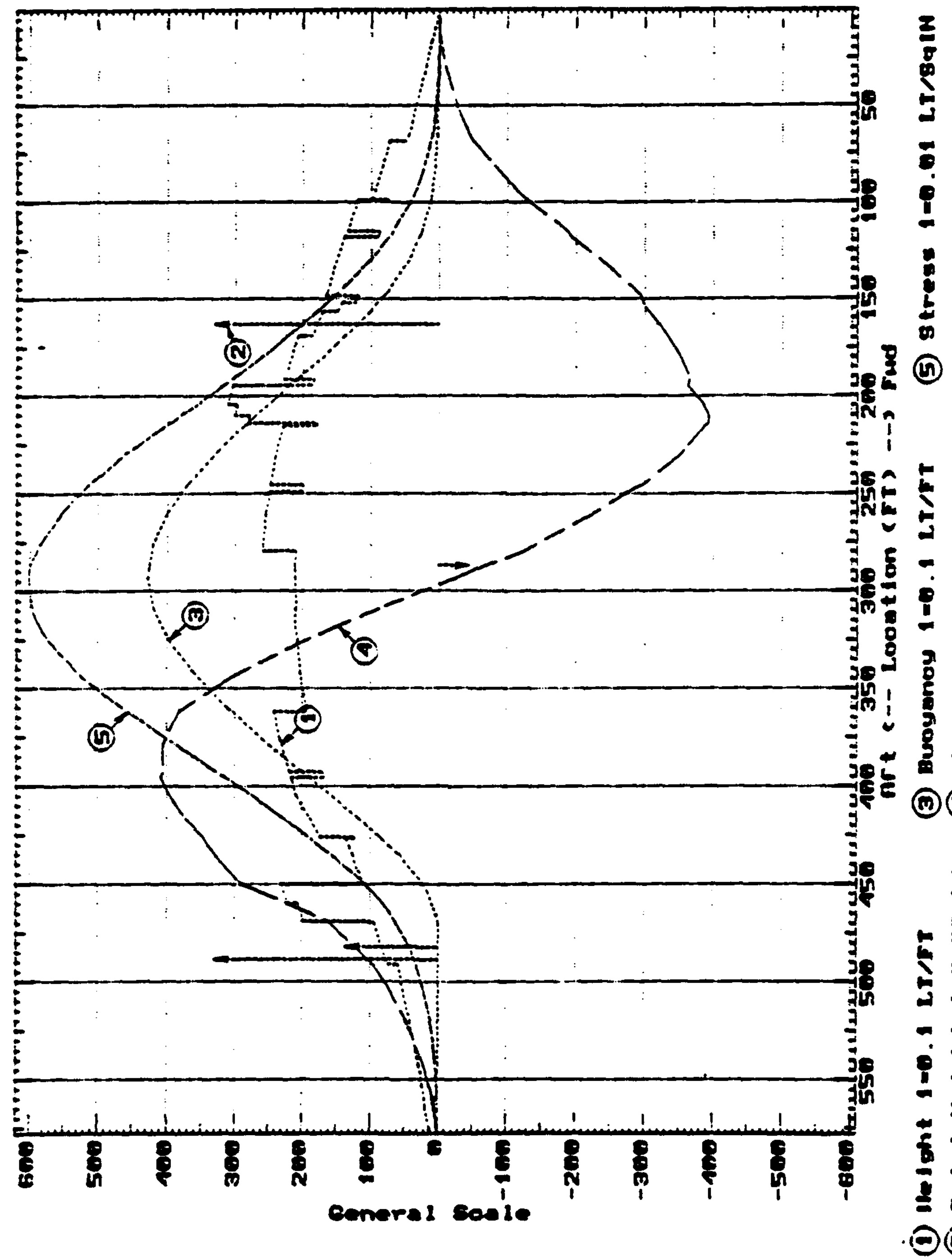
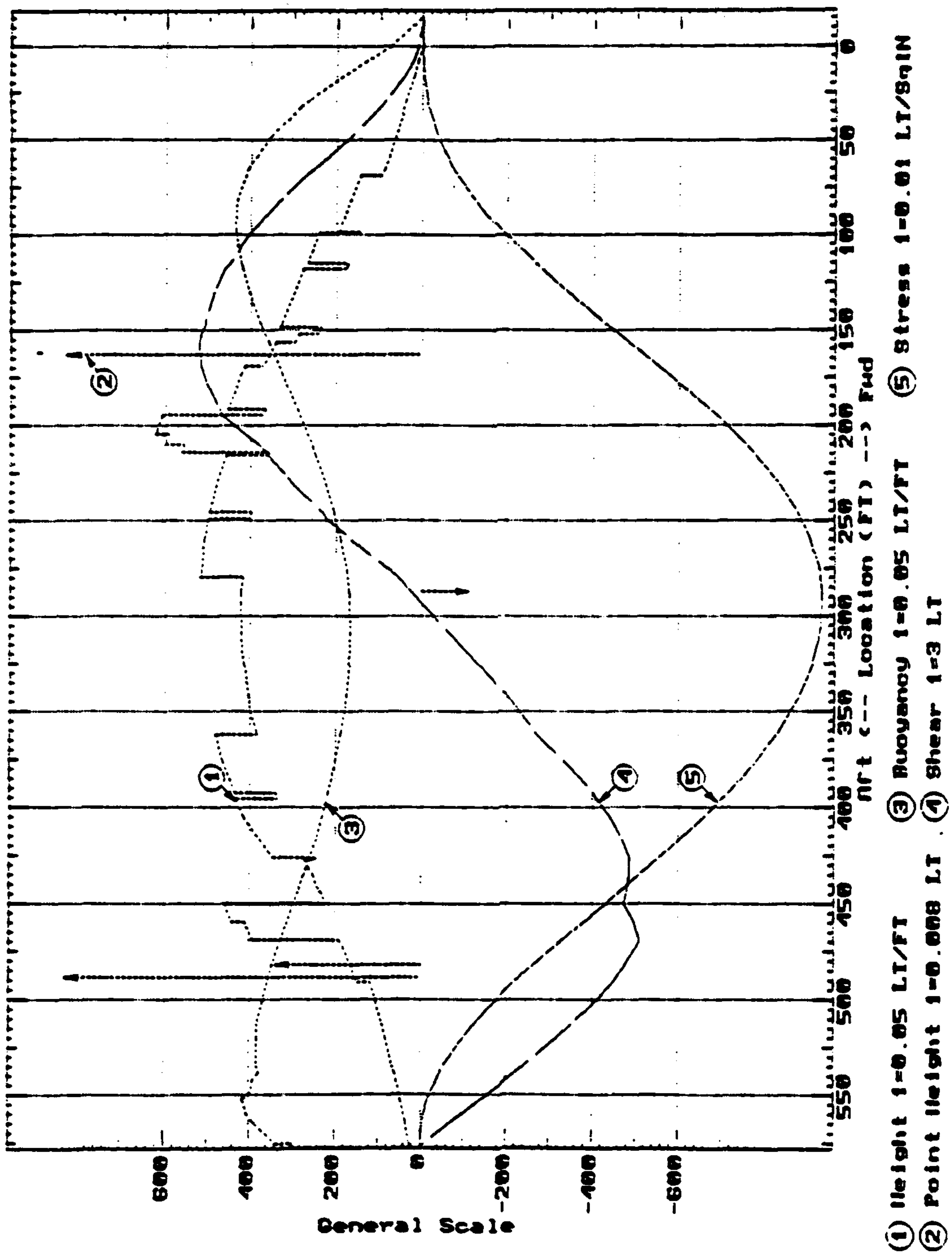


Figure 6-23. Bending Moment Curve (Sagging)



E. ENCLAVING

Survivability is one of the high priority design considerations. One technique to improve survivability is the use of enclaves. Enclaving is achieved by locating redundant equipment at different locations in the ship, reducing the overall ship vulnerability. This maximizes the ability of the ship to maintain capability in a particular warfare area, even when damaged. Cost is considered in implementing this concept by not needlessly duplicating systems with the sole purpose of increase survivability. However, by zoning required combat systems, propulsion and auxiliary equipment into regions which can function independently, or nearly independently, enclaves can be developed which achieve these goals.

The primary mission of this ship is to deliver missiles to an engagement, at low cost. This capability must be maintained though the ship may incur damage. Consideration of this primary mission along with the relatively robust combat system architecture, led the Design Team to view the division of the ship into five enclaves, two of which are each capable of accomplishing the ship's primary mission upon the loss of the other, three of which contain limited ship's capabilities. The two enclaves have components of the combat system, electrical generation system and auxiliary capability to enable the ship to launch missiles. The figure on the following page shows these enclaves.

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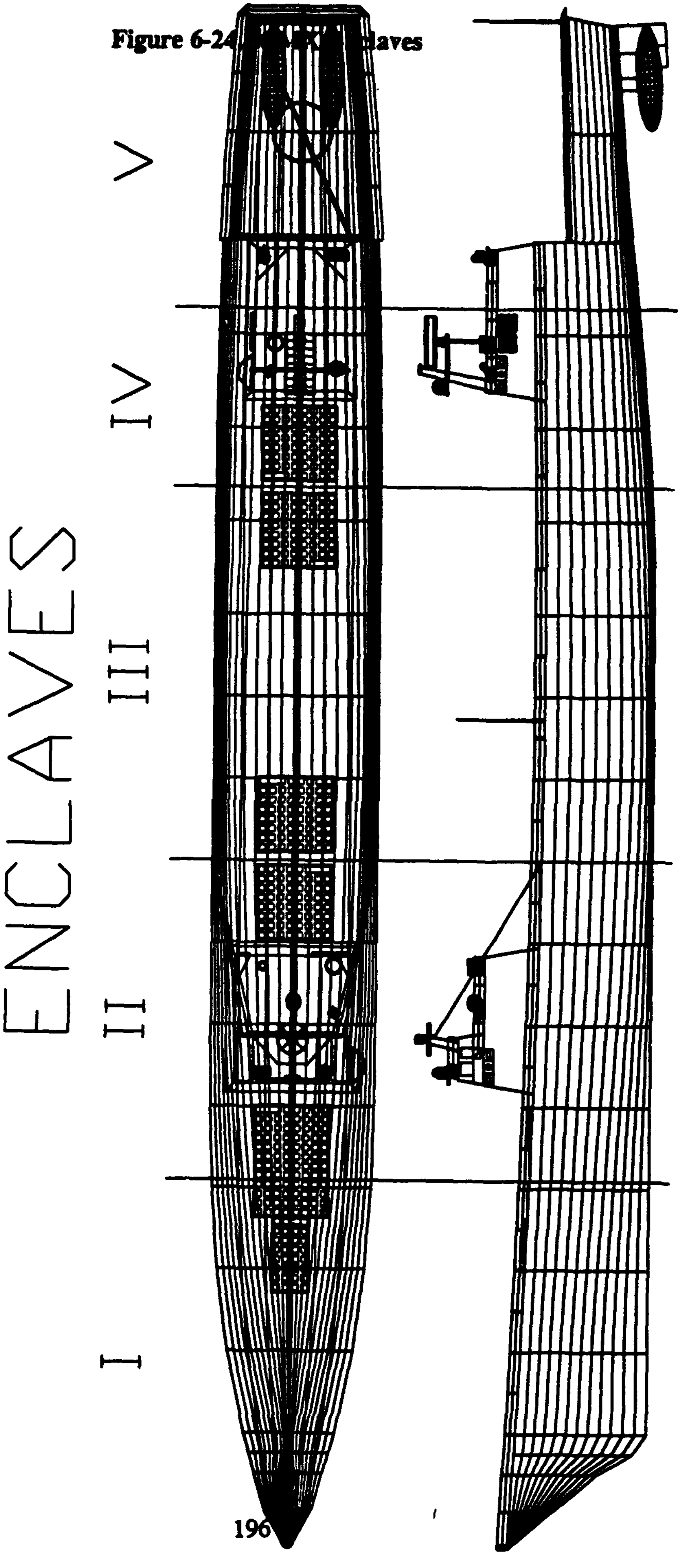
Figure 6-24 ... Enclaves



The first enclave consists of the first two VLS 'half modules' and some auxiliary systems. The second enclave includes the Gas Turbine Generator, one Main Engine, CIC, the bridge and the forward mast, two VLS modules and some auxiliary systems. The third enclave includes two VLS cells, messing facilities, most berthing and some auxiliary systems. The fourth enclave includes the second Main Engine, the Alternate CIC, Engineering Control Center, Damage Control Center, the Aft Mast and one VLS module. The fifth enclave includes some auxiliary equipment and almost all aviation elements. Important features of this enclave configuration include the following:

- The CMX propulsion system was considered to be at least as survivable as a current combatant. The power distribution system will be constructed using armored cable, which is considered to be more survivable than a shaft. Additionally, the Gas Turbine Generator can provide vital loads and emergency propulsion up to an estimated 10 knots, in the event that both main Engines are disabled. As with modern combatants, however, damage incurred in the vicinity of the screws will cripple mobility.
- The sensors have been arranged to provide adequate coverage while separating those of similar function. For example, Radiant Mist is separated from the MK 23 TAS.
- The self-defense components have also been separated. While not shown, the evolved Sea Sparrow missiles will be distributed amongst the enclaves, to maintain AAW capability even on the loss of one or more VLS module.
- Provision must be made to control Special Weapons. The Alternate CIC will have the equipment necessary for targeting and launching any weapon. The design Team proposed stationing a senior officer at ACIC, however some method would be

required to retain commanding officer's permission to fire (COPTF) in the system, in the event that CIC is damaged. An alternative is to accept the loss of special weapons capability if CIC is lost and insufficient senior officers remain, which may be appropriate in today's environment.

- The fan rooms have been arranged to facilitate a partial collective protective system. Only the second and fourth enclaves will be protected to minimize costs.

In summary, the enclaving scheme provides for a high degree of readiness and mission capability upon the loss of one enclave; "graceful degradation" is achieved. In addition, this arrangement provides an improvement over many of today's combatants, with little increased cost.

F. ARRANGEMENTS

1. Internal Arrangements

ASSET provided the Design Team with required areas for the disparate functions a ship needs to operate. The Design Team prepared arrangements drawings for these functions. The Team's primary concern was with establishing that all required functions could be accommodated in a sensible and reasonable manner. Additionally, the Team incorporated concerns for survivability, maintainability and habitability when allocating spaces. Another source that the Team drew upon was the crew of the USS Cowpens (CG63). During a visit between quarters, the team visited the Cowpens. As we expected, many of the crew had definite opinions of how their ship could be improved and what worked right. The Team incorporated those inputs that made sense into our design. Space was successfully allocated for all functions required by ASSET. Figures 6-25 through 6-28 depict the internal arrangements of all internal decks. Specific choices made include the following:

- Messing and most berthing was centrally located. The centralized galley will provide all meals to the three messes. During high tempo operations, when the messmen may be required elsewhere, the food service will make prepared meals similar to improved airline meals. These spaces are located near the midships to present low value targets to weapons which aim for the center of the ship.
- Most auxiliary equipment is separated into one of two enclaves.
- Control Stations (e.g. CIC, ECC) are placed lower in the ship to reduce vulnerability.

- VLS cells are distributed to three zones. This makes the loss of more than $^1/_3$ of the VLS cells to a single hit unlikely, given that the ship is not lost by that hit.
- The Gas Turbine Generator has a crossover in the intake and exhaust ducts. This was forced by a need to move the exhaust stack away from the forward mast, while providing sufficient height to the intake. During the Team's visit to the Cowpens, the Chief Engineer expressed a concern for sea water ingestion. Additional analysis would need to be performed to determine the pressure drop and subsequent derating of the GTG. However, since the design is not limited by power generation, this is not expected to have a major impact.
- All aviation components have been located as close to the hangar as possible.
- The CIWS Ammunition stowage was placed in the hull. The Cowpens reported that the external lockers reached elevated temperatures when painted any color other than white. Internal storage removes this solar load, but is close enough to the weapons.
- The are few rooms with large electronic cabinets. The CMX has relatively few sensors, and the Team expected that computer sizes will continue to shrink.

Figure 6-25. CMX Decks 3 and 4 Internal Arrangement

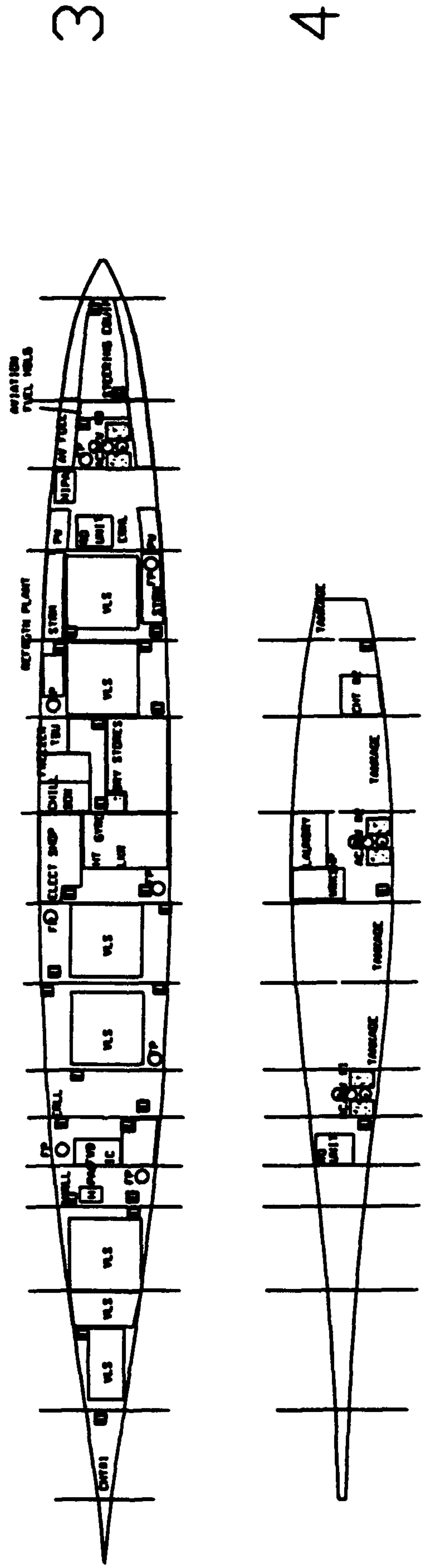


Figure 6-26. CMX Decks 1 and 2 Internal Arrangement

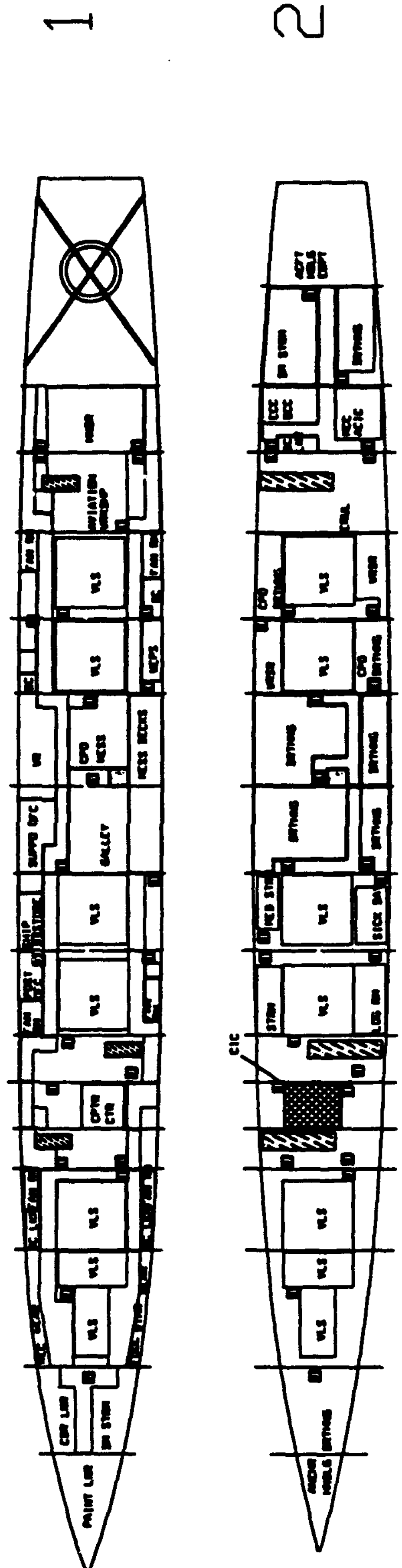


Figure 6-27. CMX 01 and 02 Level Internal Arrangements

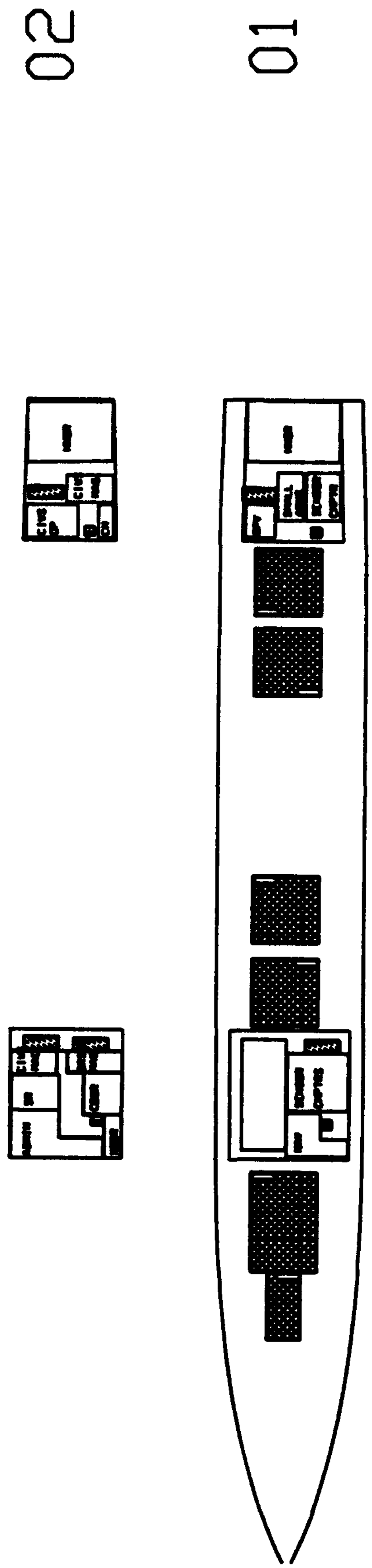
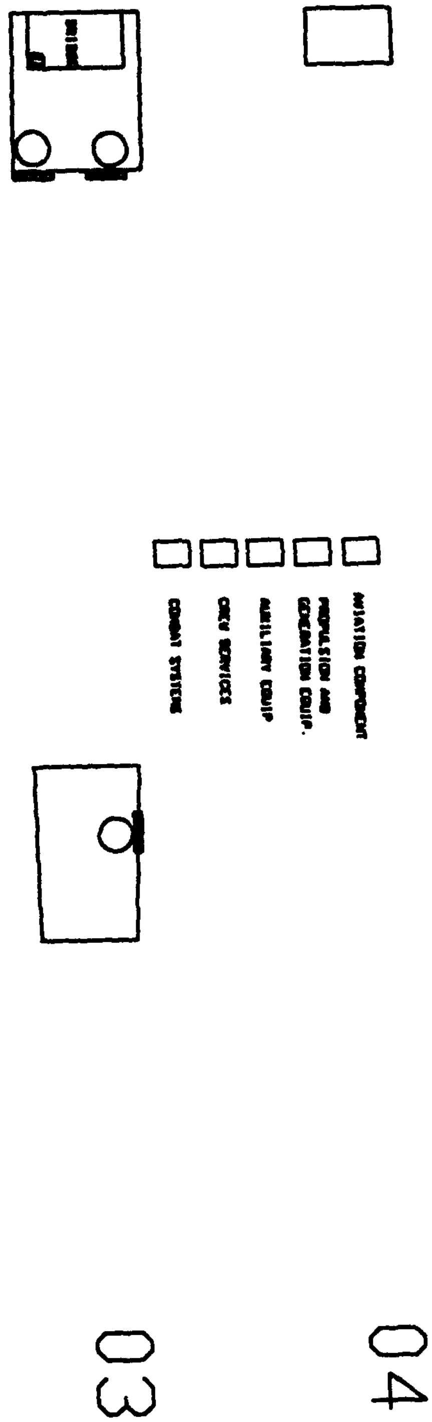


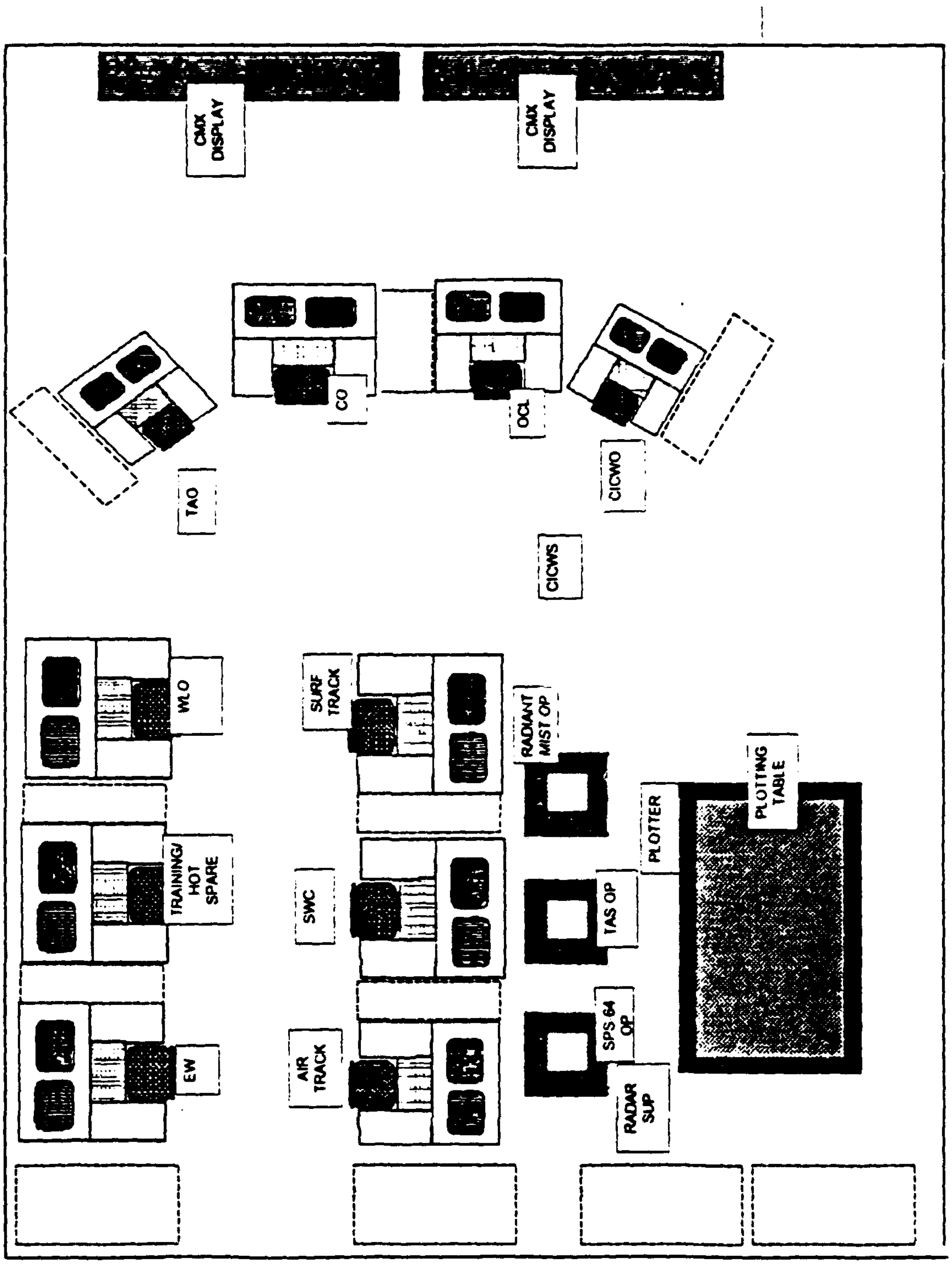
Figure 6-28. CMX 03 and 04 Level Internal Arrangement



2. Detailed Arrangements

The design Team also prepared detailed drawings of the Combat Information Center (CIC) as shown in Figure 6-29. This designs reflect the belief in reduced manning that will accrue from the implementation of *expert systems, distributed* computer architecture and interchangeability of equipment. To achieve these goals greater interaction is required between the combat systems designers, the engineering systems designers and the fleet operators.

Figure 6-29. Combat Information Center Arrangement



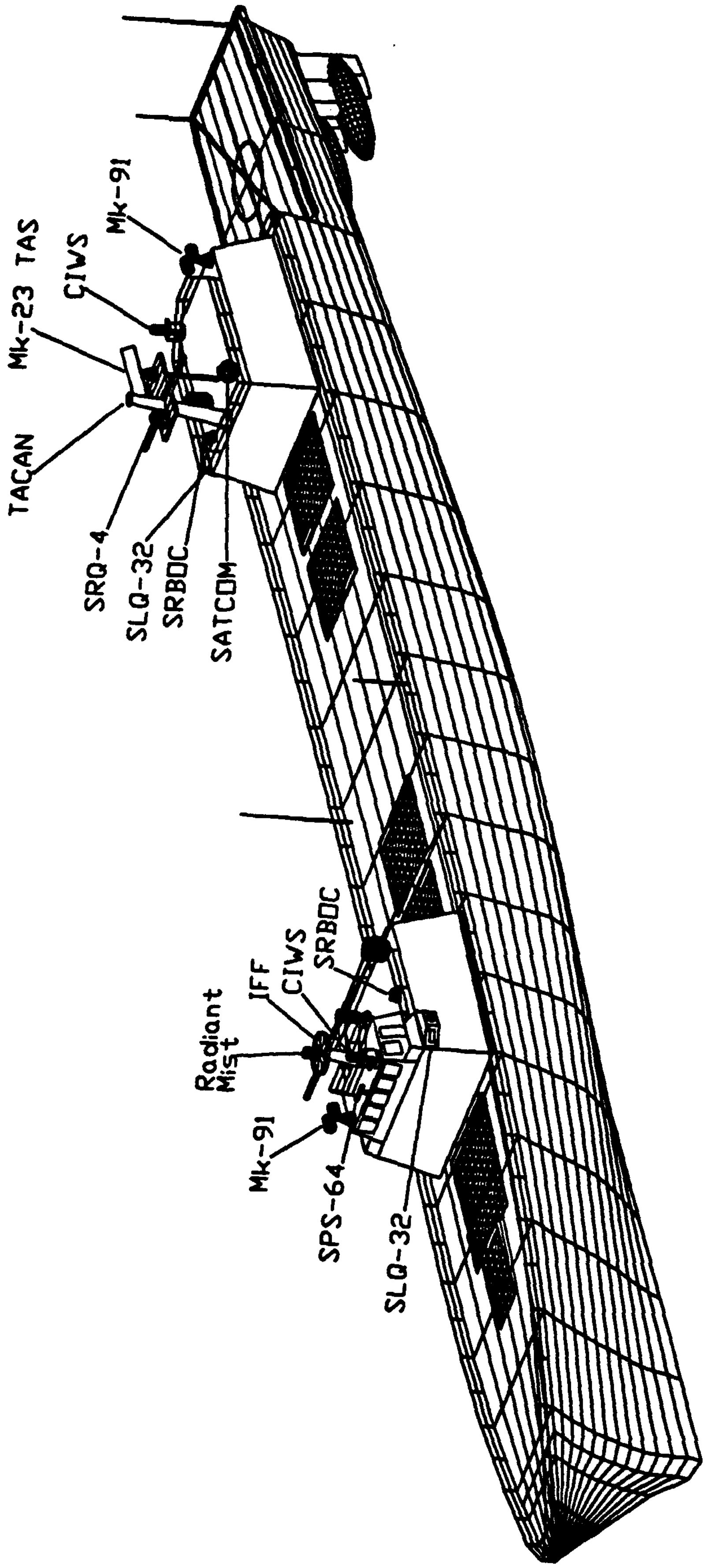
3. Topside Arrangement

A topside arrangement was also performed., ensuring that all sensor and engagement elements had effective arcs of coverage and sufficient height of eye. In addition, the elements which had similar or redundant features were separated between the forward and after superstructures in order to reduce the vulnerability of the combat system. The two major equipment locations are approximately 250 feet apart which decreases the likelihood that a single threat weapon could destroy the entire combat system effectiveness. An overview of topside arrangement is shown in Figure 6-30.

The forward superstructure and mast have a CIWS mount, Mk 91 FCS illuminator, SLQ-32, SPS-64, UHF SATCOM, MK 36 SRBOC launcher, Radiant Mist and IFF antenna array. The after superstructure and mast have the TACAN, MK-23 TAS, Lamps III communications, SLQ-32, CIWS, MK 91 FCS illuminator, UHF SATCOM, and MK 36 SRBOC launcher. In addition the smaller antennas (not shown) are located on the forward or after yardarms.

During the topside arrangements phase, the arcs of coverage of the various weapons systems were checked for adequate coverage and minimal interference. This was done solely on a geometric scale and did not involve the use of any blockage assessment models.

Figure 6-30. Topside Arrangement

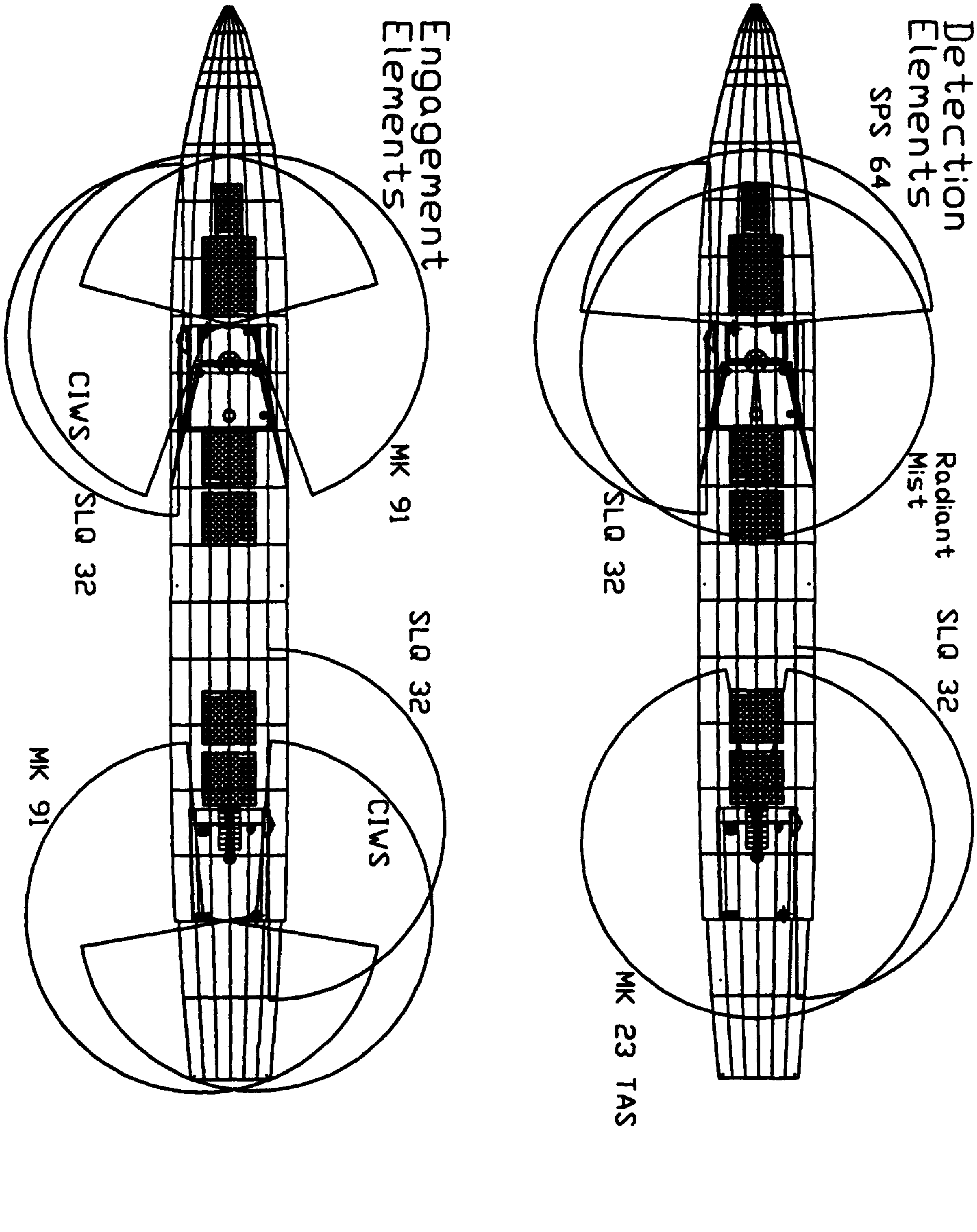


4. Arcs of Coverage

Raw data for combat system engagement and detection element arcs of coverage is provided in the table below. Overall 360 degree coverage is provided for each of the major categories. A graphical view of the arcs of coverage is provided in Figure 6-31 on the following page.

Arcs of Coverage		
Engagement Elements		360 degrees
CIWS	fwd	235 degrees total from -75 degrees R to 160 degrees R
	aft	255 degrees total from 100 degrees R to -5 degrees R
MK 91 FCS	fwd	235 degrees total from -160 degrees R to 75 degrees R
	aft	255 degrees total from 5 degrees R to -100 degrees
SLQ-32 V(3)	fwd	180 degrees total from 0 degrees R to 180 degrees R
	aft	180 degrees R to 0 degrees R
Detection Elements		360 degrees
Radiant Mist		350 degrees total from -175 degrees R to 175 degrees R
SPS-64		170 degrees total from -85 degrees R to 85 degrees R
MK 23 TAS		340 degrees total from 10 degrees R to -10 degrees R
SLQ-32 V(3)	fwd	180 degrees total from 0 degrees R to 180 degrees R
	aft	180 degrees R to 0 degrees R

Figure 6-31. CMX Arcs of Coverage



G. BATTLE ORGANIZATION AND MANNING

Cost constraints and technology advances force the designer of modern warships to examine manning considerations. Commensurate with the ship requirements and design philosophy, the Design Team examined the battle organization and with the goal of reducing manning requirements. The Team considered several important factors:

- The numbers of personnel exposed to physical risk must be reduced in the current social and political environment;
- Automation and computation advances would contribute to reducing the required level of manning;
- Current damage control procedures and equipment require extensive manpower;
- Manning has a significant impact on lifecycle cost;

The CMX has been designed with the goal of reducing manning by at least 40%, as compared to an existing combatant of the same tonnage. This reduction had been achieved in part, due to the limited Required Operational Capabilities of the CMX as compared to other combatants. The CMX would have no sonar suite and no main deck gun, which contributed dramatically to reducing manning requirements.

All offensive weapons would be stored in VLS modules. The current and foreseeable VLS weapons have limited onboard maintenance requirements. This again reduced the manning associated with the weapons system.

1. Battle Organization

To establish the battle organization requirements, the Design Team compared the watchstations required for current platforms ranging in size and complexity, from an FFG to the AEGIS cruiser. These battle organizations were then modified to incorporate the manning considerations previously discussed. The following paragraphs describe the watchstanders that would be required for the CMX, including a brief description of the duties assigned and any technical training enhancements that would be necessary for the watchstander to accomplish his assigned duties.

a. Condition III

(1) Bridge

The Design Team postulated that the bridge of the CMX would be manned as follows;

- OOD - responsible to the Commanding Officer for the safe operation of the ship;
- JOOD (when assigned) - assists the OOD in the safe operation of the ship (training watchstation);
- BMOW - supervise enlisted bridge watchstanders. Assists JOOD as required. Coordinates ship evolutions using alarms and announcements;
- Helm/Leehelm - responsible for steering the ship and coordinating engine orders with the ECC;
- QMOW - responsible for maintaining the navigation of the ship, making course/speed recommendations to the OOD;
- Lookouts (forward and aft) - responsible for the detection of visual contacts;

- **Messenger - Assists the BMOW as required (training watchstation).**

(2) CIC and MCC/ACIC

The CIC manning was dramatically reduced due to several factors:

- Reduced missions and capabilities (e.g. no sonar or gun);
- Enhanced, reconfigurable equipment;
- "Expert" computer system (programmed with with rule-based code) employment (see section A, Combat System Integration and Management);

The CIC on the CMX would be the Primary OCL station. The Maintenance Control Center/Auxiliary CIC would have the capability to support OCL launch independently. The CMX combat system would be an advanced network with computer system, enhanced with artificial intelligence programming, to assist the operators. Since the CMX would not have significant long range sensors, it would not be a major source of target input data into the link. It would primarily be concerned with the tactical threat to own ship and maintaining the ability to provide OCL weapons to the battlegroup. During normal steaming the Maintenance Watch would be located at the MCC/ACIC. If a casualty occurs to CIC, additional personnel would be assigned to man MCC/ACIC and sufficient computational power, electric backup and communication equipment would be available to ensure that OCL capability would be maintained.

Based on these concepts, CIC on the CMX would be manned as follows;

- TAO - responsible to the Commanding Officer for the tactical employment of the ships sensors and weapons systems;
- CICWO - Officer in charge of CIC functions. Assistant to the TAO.;
- CICWS - Supervises the CIC watchstanders in detecting and tracking and contacts;
- Surface Tracker - Responsible for maintaining the updating of all tactical surface contacts;
- Air Tracker - Responsible for maintaining the updating of all tactical air contacts;
- TIC/OCL Officer - Responsible for monitoring and maintaining the OCL system, and tracking and correlating EW contacts;
- Magazine Rover - Responsible for inspection of the magazines, small arms and self defense weapons;
- Maintenance Watch (MCC/ACIC) - Responsible monitoring the ship's computer systems, initiates repair actions and reconfigurations the combat systems;
- Messenger - Assists the CICWS as required (training watchstation).

(3) Engineering

The manning requirements for the engineering plant were reduced by adopting the same type of organization and equipment control and monitoring as was postulated for the combat system. The Engineering Control Center (ECC) would be combined with Damage Control Central (DCC). The EOOW would oversee both functions during routine operations. As the ship is electric drive and only has two main engines and two GTG's, the Design Team felt that there could be one operator responsible for both the main engines and electrical generators. The

Engineering SYS-OP/SYS-READ system (see section B, Hull, Mechanical and Electrical) would assist that operator during casualties. As discussed, this computer system would monitor the ship's equipment status, the electrical load and the requirements of the combat system. This system would also provide load shedding logic to the Main Engine Control Panel.

In a similar manner, there would be an Auxiliaries Control Panel (ACP) watch. This watch would be capable of operating all auxiliaries remotely including the air compressors, reverse osmosis (RO) units, refrigeration and air conditioning plants and trash disposal system.

Damage Control would be centrally coordinated at the Damage Control Panel (DCP). A subset of the Engineering Readiness System, the Damage Control Readiness System (DC/SYS-READ) (see section B, Hull, Mechanical and Electrical), would incorporate space sensors providing indications including temperature and water level to the DCP. If video is included in DC/SYS-READ then a visual indication of the status of the space can be provided as well. This watch, the DC Rover, would also rove the ship, checking equipment status. While the DC Rover is touring the ship, the other ECC watchstanders would monitor the DCP as required.

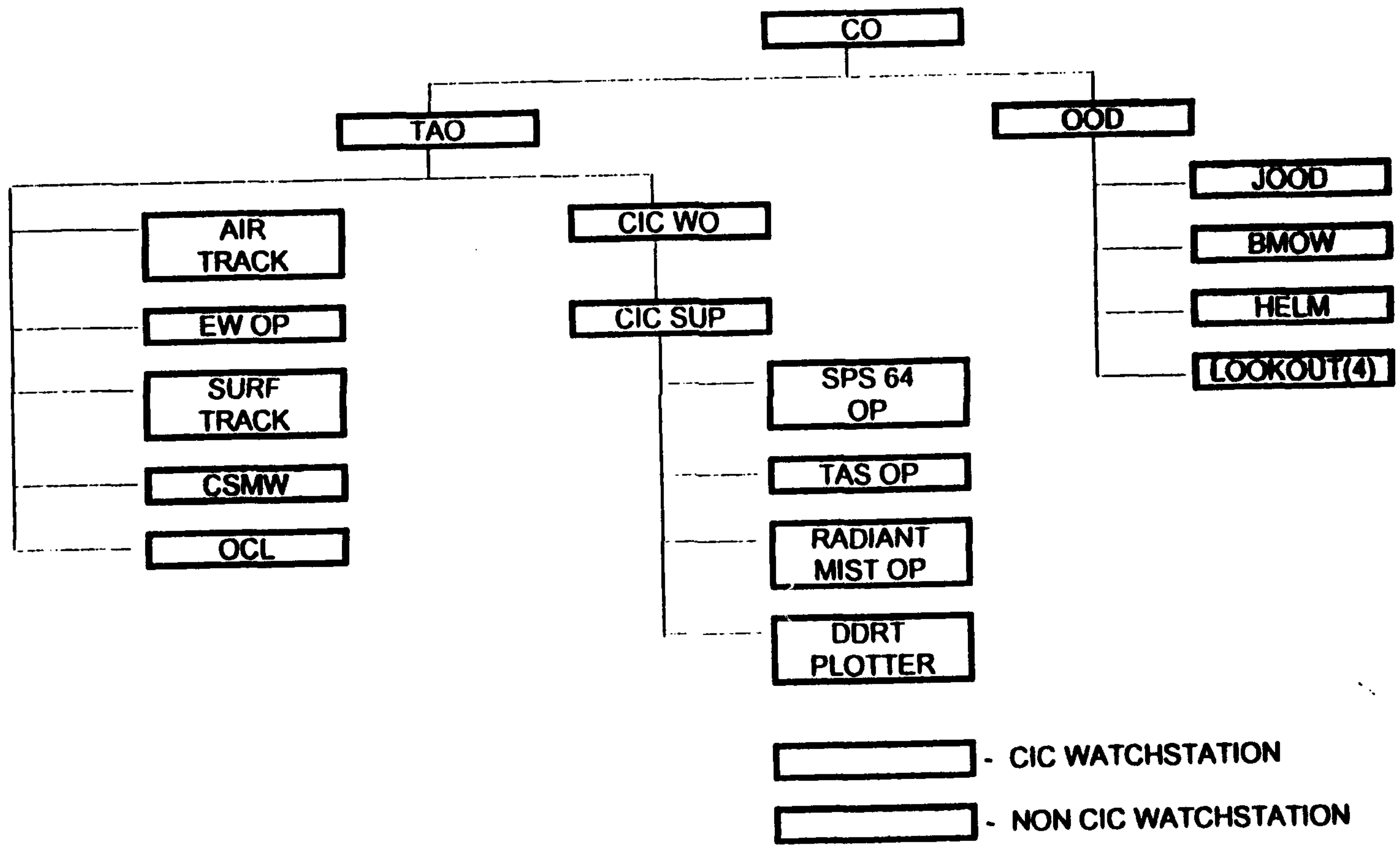
Based on these concepts, the Team postulated the engineering plant for the CMX would be manned as follows:

- EOOW - Senior engineering plant watchstander, responsible to the OOD for safe operation of engineering equipment, including main propulsion, electrical and auxiliaries;
- Main and Electrical Control Panel (MECP) operator - Responsible for the safe operation and monitoring of the main engines and electrical distribution system;

- Auxiliary Control Panel (ACP) watch - Responsible for the safe operation and monitoring of the auxiliary systems;
- Engineering Plant Supervisor (EPS) - Senior roving watch, responsible for supervising locally operations directed or required by ECC/DCC;
- Main Machinery Rover - Responsibly for inspecting and monitoring the local integrity of the main machinery equipment and spaces (training watchstation);
- DC Rover- Responsible for the operation and monitoring of damage control equipment, both remotely from DCC, and locally when required. Maintains the status of the Damage Control Panel (DCP).

The figure on the following page shows the battle organization for the CMX in Condition III.

Figure 6-32. Watch Organization (Condition III)



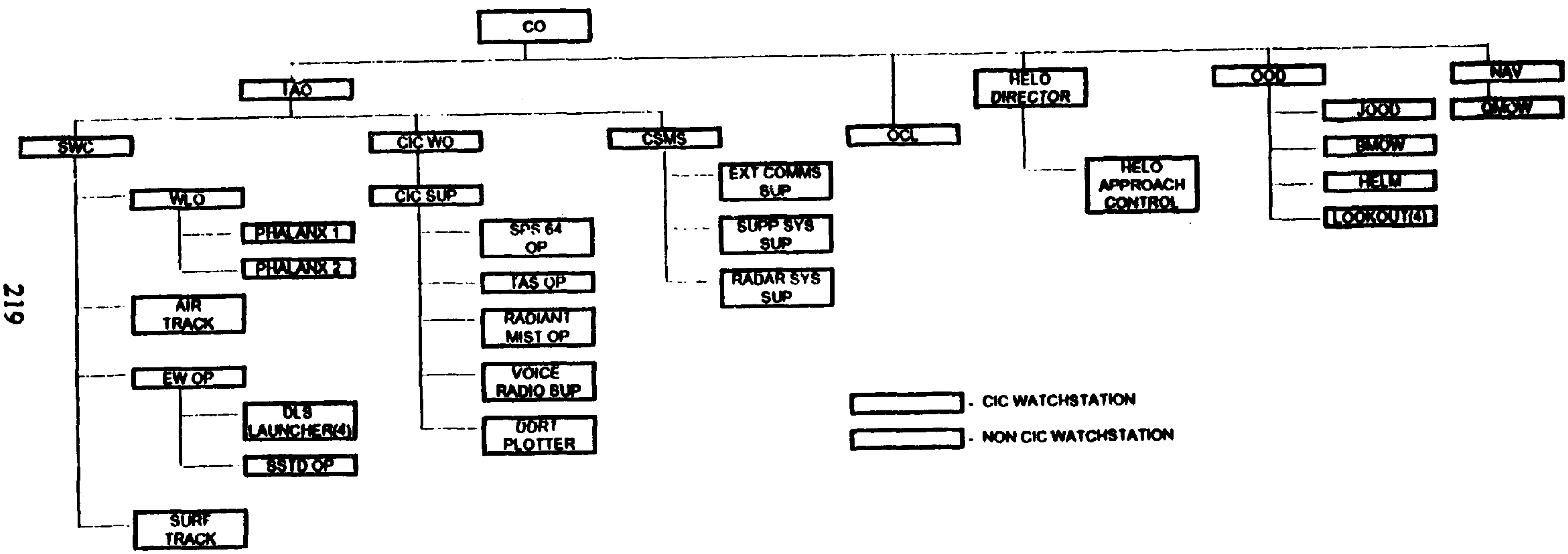
b. Condition I

A much higher state of readiness is required for the CMX during Condition I. More watchstations are manned and the personnel assignments are carefully chosen to employ the experience of the personnel in the most effective manner. The additional Condition I watchstations include the following:

- Combat System Maintenance Supervisor (CSMO) - responsible for supervising entire ship's computer systems;
- Helo Director - responsible for safe operations, helo preparations and loadouts;
- Helo Approach Control - responsible helo guidance during takeoffs and landings;
- Weapons Liaison Officer (WLO) - directs operations of the CIWS systems.

The figure on the following page shows the battle organization for the CMX in Condition I.

Figure 6-33. Watch Organization (Condition I)



2. Manning

ASSET provided a first approximation of the crew size required, based on parametric studies of historical ships (see Appendix F). The Design Team performed an analysis of the manning to determine if the projected manning was feasible. One of the priorities of the ship design was to reduce the manning required. This will dramatically reduce lifecycle costs of the ship but does require changes in the way ships are managed.

Some technological advances, discussed in other sections, must be incorporated into the ship organization to accomplish significant manning reduction. Some long practiced traditions must also be modified to allow this level of manning. One such tradition is the method of accomplishing routine preservation. The Design Team felt the system of preservation used by foreign navies, such as the British Royal Navy, *should* be considered. In this system, most major preservation is done by contractors. The ship is granted a pool of money which it spends on preservation, as required. This reduces the crew size as we are not using highly trained sailors to accomplish low wage work. The ASSET program indicated that about one third of the required man-hours were not available. Using programs like the painting scheme described above, should make up the shortfall.

The following tables show the projected manning for the CMX. The first table shows the breakdown of the officers and crew, and the following table shows the breakdown of the crew by rate.

Manning Breakdown (Officers and Crew)					
DEPT	**DHs**	**DOs**	**CPOs**	**<E7**	**SUBTOTAL**
CO					1
ADMIN/MEDICAL	1*	0	1	6	6
NAV/OPS	0	3	3	34	45
ENGINEERING	1	3	3	43	50
COMBAT	1	3	5	45	54
SUPPLY	1	0	2	18	18
AIR DET	0	3	1	7	11
TOTALS	4	12	15	150	185

* XO to act as ADMIN/MEDICAL DH

Manning Breakdown (Crew, by rate)			
ADMIN/MEDICAL	YN/PN	4	
	HM	2	
		TOTAL	6
NAV/OPS	QM	4	
	OS	10	
	SM	5	
	BM	15	
		TOTAL	34
COMBAT	EW,ET,DS	10	
	FTM	15	
	GMM,GMT	20	
		TOTAL	45
ENGINEERING	GSM,FN	10	
	EM.GSE	12	
	HT,DC	11	
	EN,MR,MM	10	
		TOTAL	43
SUPPLY	SH,SK	5	
	MS,SN,FN	13	
		TOTAL	18

VII. SUMMARY

As the Design Team concluded the technical aspect of the project, a review of the requirements was conducted. The Design Team feels the CMX design meets or exceeds the goals established. The vessel is very near the design budget, delivers a significant number of weapons efficiently, has a very effective self-defense suite and incorporates new technologies in an innovative manner.

The electric drive, podded propulsion system, the ship integration and management computer system, and the availability of VLS configured variants of certain advanced weapons pose some technical risk for the CMX design. However, the Team's research in these areas indicates that all elements are achievable within the next 15 years.

As students, the Team made a conscious effort to minimize the impact of traditional design practices in various areas. Our approach to manning, equipment automation, preservation and missile control was intended to challenge some paradigms we believe constrain ship design. Another area the Team wanted to consider was zonal auxiliaries. Time constraints prevented complete development of this area, but it has the potential for a positive effect on survivability.

The Design Team feels that the product is a good first iteration of a large capacity missile carrier design. Its capabilities and limitations have been thoroughly explored and hopefully, within the scope of the student project.

A. CONCLUSIONS

With respect to the goal of familiarizing the members of the Student Design Team with the nuances involved in the design of U.S. Navy ships, the project was clearly a success.

In retrospect, certain effects which most strongly impacted the system design were not engineering in nature. For example, the Team encountered various boundary conditions which necessarily limited the scope and accuracy of the design. Of these conditions, the most limiting was that of time. The restricted number of man-hours which could be devoted to the design of the CMX limited the project to one "loop" around the design spiral, and only allowed a cursory investigation into some regions on that loop; i.e., the structural design.

The next most significant boundary condition was the Team's lack of experience in using the tools of the trade. Specifically, a large portion of our effort was devoted to learning how to use ASSET and AUTOCAD©. As a result, we were not able to investigate numerous types of monohulls or other hull forms. This, however, was not the purpose of this academic exercise.

Another impact was that of Design Team organization. Because the group contained no experts in any one field, the division of labor was somewhat arbitrary (based to a small extent on individual interests). Thus, the design and/or analysis of a given system was largely dependent upon the "designated expert's" ability to master the subject. More than anything else, this technical weakness on the Team's part occasionally led to efforts having to be reworked once the inadequacies of a system's design became apparent.

B. RECOMMENDATIONS

For the Design Team, the most significant gap in the design process was bridging between feasibility studies and preliminary design. Although it is an excellent tool for monohull feasibility studies, the ASSET program lacks the flexibility to easily analyze other types of hull forms, and does not provide the details necessary to develop a preliminary design (even given the limited scope of preliminary design that was within the student team's capabilities). We, therefore, make the following recommendations for future TSSE research efforts:

- Enhance ASSET's capabilities with respect to non-conventional type hull designs; specifically, SWATH-type hull forms.
- Incorporate into ASSET the ability to specify the dimensions of the payload items. This would make the hull volume design calculations much more reliable.
- Build-in to ASSET a data bank of commonly used payloads; i.e., radars, sonars and missiles.
- Develop a hydrodynamic analysis code which would take output from a CAD drawing and determine its hydrodynamic characteristics. This would allow the design and analysis of exotic hulls without the encumbrance of having to specify all of the details required by ASSET. When coupled with the output of ROM studies, one could quickly examine many hull forms to ferret out the most promising choices among the numerous possibilities, without being forced to commit to a specific hull design early in the feasibility studies.

- Develop a routine—either an addition to ASSET or a separate finite element code—which would allow detailed structural analysis of the midships section.
- Develop databases that would allow the performance of ROM and measure-of-effectiveness (MOE) studies.

Finally, the Design Team felt strongly that the knowledge and insight gained from the ship visit was invaluable, and should be incorporated as a permanent part of the TSSE curriculum.

REFERENCES

1. *The Naval Institute Guide to Combat Fleets of the World 1993*, ed. Prezelin, B., 1993.

2. *The Naval Institute Guide to World Naval Weapons Systems*, ed. Friedman, N., 1989.

3. *The Naval Institute Guide to Ships and Aircraft if the U.S. Fleet, 15th Edition*, ed. Polmar, N., 1993.

4. *Principles of Naval Architecture, 2nd Revision*, Society of Architects & Marine Engineers, 1988.

5. *Surface Ship Combat System Master Plan*, Naval Sea Systems Command, January 1993.

6. *Manual for Naval Surface Ship Design Technical Practices*, Naval Sea Systems Command, T-9070-AA-MAN-010/(C).

7. *Advanced Surface Ship Evaluation Tool (ASSET), User Manual*, David Taylor Research Center, 1990.

8. Rains, D., "Reduced Vulnerability Through Ship Arrangements", *Decision Engineering Brief*, July 1992.

9. Hensler, J., "Electric Ship Propulsion: Applications and Integration", *SNAME Transactions, Volume 97*, 1989.

10. Hultgren, K., "VSCF Cycloconverter Ships Service Power Equipment", *Naval Engineers Journal*, January 1992.

11. Gilmer, T. and Johnson, B., *Introduction to Naval Architecture*, Naval Institute Press, 1982.

12. *Manual for General HydroStatics (GHS) by Creative Systems*, Creative Systems, Inc., 1993.

13. Falatko, S., Zitman, L., Papach, J., "Computer System Architecture Concepts for Future Combat Systems, *Naval Engineer's Journal*, May 1990.

14. Atlas Electronik GMBH, *Our Products and Services, Navy Division*, Bremen, Germany, 1992.

15. Burgess, E., *Long Range Ballistic Missiles*, Macmillan, 1961.

16. Nicholas, T., Kossi, R. *U.S. Weapon Systems Costs*, Data Search Associates, 1991.

APPENDICES

APPENDIX A

SHIP CHARACTERISTICS

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Ticonderoga	MK 26 Launcher(1)	SM-2 MR	24	SURF	HORIZ	0.75
				AIR	35	0.75
		ASROC w/MK46	20	SUB	5	0.6
	MK 26 Launcher (1)	SM-2 MR	24	SURF	HORIZ	0.75
				AIR	35	0.75
	MK45 127mm/54 (2)	127mm Burst	198	SURF	9.7	0.6
				AIR	4.9	0.4
		127mm Deadeye LGB	70	SURF	15	0.8
	MK15 Phalanx CIWS (2)	20mm Burst	10	SURF	0.3	0.2
				AIR	0.8	0.8
	MK32 324MM TT (2)	MK50 Barracuda	6	SUB	6	0.7

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Ticonderoga VLS	MK41 VLS	SM-2 MR BLOCK II	61	SURF	HORIZ	0.75
				AIR	35	0.75
	MK41 VLS	SM-2 MR BLOCK II	37	SURF	HORIZ	0.75
				AIR	35	0.75
		VLS ASROC w/ MK50	12	SUB	5	0.6
		Tomahawk	12	SURF	450	0.7
	MK45 127mm/54 (2)	127mm Burst	198	SURF	9.7	0.6
				AIR	4.9	0.4
		127mm Deadeye LGB	70	SURF	15	0.8
	MK15 Phalanx CIWS (2)	20mm Burst	10	SURF	0.3	0.2
				AIR	0.8	0.8
	MK32 324MM TT (2)	MK50 Barracuda	6	SUB	6	0.7
	MK141(2)	Harpoon 1C	8	SURF	80	0.8

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Arleigh Burke	MK41 VLS	SM-2 BLOCK IV	29	SURF	HORIZ	0.8
				AIR	60	0.8
	MK41 VLS	SM-2 BLOCK IV	37	SURF	HORIZ	0.8
				AIR	60	0.8
		VL ASROC w/ MK50	12	SUB	20	0.7
		Tomahawk	12	SURF	450	0.75
	MK45 127mm/54 (2)	127mm Burst	99	SURF	9.7	0.6
				AIR	4.9	0.4
		127mm Deadeye LGB	35	SURF	15	0.8
	MK15 Phalanx CIWS (2)	20mm Burst	16	SURF	0.3	0.2
				AIR	0.8	0.8
	MK32 324MM TT (2)	MK50 Barracuda	6	SUB	6	0.7
	MK141(2)	Harpoon 1C	8	SURF	80	0.8

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Arleigh Burke Flight IIA	MK41 VLS	SM-2 BLOCK IV	29	SURF	HORIZ	0.8
				AIR	60	0.8
	MK41 VLS	SM-2 BLOCK IV	37	SURF	HORIZ	0.8
				AIR	60	0.8
		VL ASROC w/ MK50	12	SUB	20	0.7
		Tomahawk	12	SURF	450	0.75
	MK45 127mm/54 (2)	127mm Burst	99	SURF	9.7	0.6
				AIR	4.9	0.4
		127mm Deadeye LGB	35	SURF	15	0.8
	MK15 Phalanx CIWS (2)	20mm Burst	16	SURF	0.3	0.2
				AIR	0.8	0.8
	MK32 324MM TT (2)	MK50 Barracuda	6	SUB	6	0.7
	MK141(2)	Harpoon 1C	8	SURF	80	0.8

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Kidd	MK26 Rail Launcher	SM-2MR	24	SURF	HORIZ	0.75
				AIR	35	0.75
	MK26 Rail Launcher	SM-2MR	24	SURF	HORIZ	0.75
				AIR	35	0.75
		ASROC w/ MK46	20	SUB	5	0.6
		Tomahawk	12	SURF	450	0.75
	MK45 127mm/54 (2)	127mm Burst	198	SURF	9.7	0.6
				AIR	4.9	0.4
		127mm Deadeye LGB	70	SURF	15	0.8
	MK15 Phalanx CIWS (2)	20mm Burst	16	SURF	0.3	0.2
				AIR	0.8	0.8
	MK32 324MM TT (2)	MK50 Barracuda	6	SUB	6	0.7
	MK141(2)	Harpoon 1C	8	SURF	80	0.8

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Kirov (Kirov)	SA-N-6 VLS	Grumble	96	SURF	HORIZ	0.6
				AIR	50	0.7
	SS-N-19 VLS	Shipwreck	20	SURF	250	0.8
	AK-630 (4)	20mm Burst	60	SURF	1.6	0.75
				AIR	1.6	0.75
	SA-N-4	Gecko	40	SURF	8	0.55
				AIR	8	0.5
	Auto 130mm/70 Burst( )	100mm Burst	240	SURF	6.5	0.5
				AIR	4.3	0.4
	RBU 6000	Mortar Shell	16	SUB	3.2	0.25
	RBU 1000	Mortar Shell	12	SUB	0.5	0.3
	SS-N-14	E45-75A	14	SUB	30	0.3

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Kirov (Frunze)	SA-N-6 VLS	Grumble	96	SURF	HORIZ	0.6
				AIR	50	0.7
	SS-N-19 VLS	Shipwreck	20	SURF	250	0.8
	AK-630 (4)	20mm Burst	60	SURF	1.6	0.75
				AIR	1.6	0.75
	SA-N-4	Gecko	40	SURF	8	0.55
				AIR	8	0.5
	Auto 130mm/70 Burst( )	130mm Burst	120	SURF	6.5	0.5
				AIR	4.3	0.4
	RBU 6000	Mortar Shell	16	SUB	3.2	0.25
	RBU 1000	Mortar Shell	12	SUB	0.5	0.3
	SS-N-14	E45-75A	14	SUB	30	0.3
	533mm TT	SET-65	8	SUB	11	0.55

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Kirov (Kalinin)	SA-N-6 VLS	Grumble	96	SURF	HORIZ	0.6
				AIR	50	0.7
	SS-N-19 VLS	Shipwreck	20	SURF	250	0.8
	CADS N-1(6)	30mm Burst	90	SURF	1.6	0.75
				AIR	1.6	0.75
		CIWS Missile	48	AIR	6	0.7
	SA-N-4	Gecko	40	SURF	8	0.55
				AIR	8	0.5
	Auto 130mm/70 Burst( )	130mm Burst	120	SURF	9.5	0.5
				AIR	5	0.4
	RBU 12000	Mortar Shell	10	SUB	6	0.2
	RBU 1000	Mortar Shell	12	SUB	0.5	0.3
	SA-N-9 VLS (4)	SA-N-9	144	AIR	8	0.7
	533mm TT	SET-65	8	SUB	11	0.55

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Slava	SA-N-6 VLS	Grumble	64	SURF	HORIZ	0.6
				AIR	50	0.7
	SS-N-12	Sandbok	16	SURF	300	0.8
	AK-630 (4)	20mm Burst	60	SURF	1.6	0.75
				AIR	1.6	0.75
	SA-N-4	Gecko	40	SURF	8	0.55
				AIR	8	0.5
	Auto 130mm/70 Burst( )	130mm Burst	120	SURF	9.5	0.5
				AIR	5	0.4
	RBU 6000	Mortar Shell	10	SUB	3.2	0.25
	SA-N-9 VLS (4)	SA-N-9	144	AIR	8	0.7
	533mm TT	SET-65	4	SUB	11	0.55

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Sovremmenny	SA-N-7	Gadfly	44	SURF	15	0.6
				AIR	15	0.7
	SS-N-22	Sunburn	8	SURF	65	0.8
	AK-630 30mm (2)	30mm Burst	30	SURF	1.6	0.75
				AIR	1.6	0.75
	Auto 130mm/70 Burst(2)	130mm Burst	240	SURF	9.5	0.5
				AIR	5	0.4
	RBU 1000	Mortar Shell	12	SUB	0.5	0.3
	SA-N-9 VLS (4)	SA-N-9	144	AIR	8	0.7
	533mm TT	SET-65	8	SUB	11	0.55

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Udaloy	SA-N-9 VLS	SA-N-9	64	AIR	8	0.7
	AK-630 (2)	20mm Burst	60	SURF	1.6	0.75
				AIR	1.6	0.75
	SA-N-4	Gecko	40	SURF	8	0.55
				AIR	8	0.5
	Auto 100mm/70 Burst( )	100mm Burst	240	SURF	6.5	0.5
				AIR	4.3	0.4
	RBU 6000	Mortar Shell	16	SUB	3.2	0.25
	533 mm TT	SET-65	8	SUB	11	0.55
	SS-N-14	E45-75A	14	SUB	30	0.3

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Mod Udaloy	SA-N-9 VLS	SA-N-9	64	AIR	8	0.7
	AK-630 (2)	20mm Burst	60	SURF	1.6	0.75
				AIR	1.6	0.75
	SA-N-4	Gecko	40	SURF	8	0.55
				AIR	8	0.5
	Auto 130mm/70 Burst( )	130mm Burst	120	SURF	9.5	0.5
				AIR	5	0.4
	533 mm TT	SET-65	8	SUB	11	0.55
	SS-N-14	E45-75A	8	SUB	30	0.3
	CADS N-1(2)	30mm Burst	30	SURF	1.6	0.75
				AIR	1.6	0.75
		CIWS Missile	16	AIR	6	0.7

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Krivak	SA-N-9 VLS	SA-N-9	64	AIR	8	0.7
	AK-630 (2)	20mm Burst	60	SURF	1.6	0.75
				AIR	1.6	0.75
	SA-N-4	Gecko	40	SURF	8	0.55
				AIR	8	0.5
	Auto 130mm/70 Burst( )	130mm Burst	120	SURF	9.5	0.5
				AIR	5	0.4
	533 mm TT	SET-65	8	SUB	11	0.55
	SS-N-14	E45-75A	8	SUB	30	0.3
	CADS N-1(2)	30mm Burst	30	SURF	1.6	0.75
				AIR	1.6	0.75
		CIWS Missile	16	AIR	6	0.7

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Nanuchka II	SS-N-2C	Styx	4	SURF	43	0.65
	SA-N-4	Gecko	20	SURF	8	0.55
				AIR	8	0.5
	57 mm/ 70	57mm Burst	120	SURF	2.7	0.25
				AIR	2.7	0.15

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Osa II	AK-230 (2)	30mm	240	SURF	1.6	0.3
				AIR	1.6	0.3
	SA-N-5	Grail	4	AIR	3	0.3
	SS-N-2B	Styx	4	SURF	25	0.4

Ship Class	Weapons system	Ammunition	Qty	Target	Range	PK
Combattante IIG	Otomat Mk1	Otomat	4	SURF	32	0.75
	DARDO	40 mm Burst	120	SURF	2.2	0.6
				AIR	2.2	0.75
	Compact 76mm	76 mm Burst	120	SURF	4.3	0.4
				AIR	2.7	0.4
	SUT Torpedo	SUT	2	SUB	15.3	0.7
				SURF	15.3	0.7

APPENDIX B

THREAT WEAPON MODELS

To conduct combat system performance and effectiveness analyses, the Design Team developed a set of threat weapons models.

A survey of the current threat weapon inventory was conducted using the open literature found in the Naval Postgraduate School Library. Based upon this survey, a list of threat weapons was developed that the Team felt were representative of the likely threat missiles the CMX would encounter. Using open literature allowed the Team to keep this portion of the design unclassified and reduced the time that would be needed to evaluate all possible threats.

1. General Descriptions

The potential threat missiles were categorized into four types, represented by the following fictitious names:

- Trasher
- Takeover
- Seagull
- Sunstroke

The Trasher missile is an air launched high speed anti-radiation missile designed to suppress the radars of a target. The warhead is small at 10 kilograms but designed to destroy the relatively unprotected antennas of the radar system.

The Takeover missile is an air launched anti-ship missile with active radar guidance and a large 1000 kilogram warhead. It cruises to the target at an altitude of 50,000 feet with a terminal dive to the target at a 50° angle and is designed to sink or severely disable ships through its large blast effect and penetrating warhead.

The Seagull missile is a ship or air launched subsonic sea skimming anti-ship missile. It has a semi-armor piercing warhead of 110 kilograms. It uses active radar for guidance and is designed to disable a ship by blast damage within the hull of the ship.

The Sunstroke missile is an air or surface launched high speed sea skimming anti-ship missile. The warhead is relatively small at 50 kilograms but the high speed of the missile decreases the likelihood that it will be shot down. Also, the warhead is designed to disable a ship by blast effects.

2. Threat Weapon Parameters

The following table lists the performance characteristics of the threat weapons developed:

Threat Weapon Parameters

Designated Name	Radar Cross-section (m^2)	Speed (Mach)	Range (nm)	Warhead Weight (kg)	Guidance	Profile Trajectory
Trasher (A-S)	0.05	2.5	40	10	Passive Radar	Homes on Radar
Takeover (A-S)	0.7	3.4	300	1000	Active or Passive Radar	High Altitude w/50° terminal dive to target
Seagull (S-S)	0.11	0.7	15	110	Active Radar	15 meter sea skimmer
Sunstroke (S-S)	0.2	2.5	65	50	Active Radar	10 meter sea skimmer
Small Mines	R=1 ft			500		moored mine
Spikefish Torpedo	533mm dia.	60 kts	25000 yds	500	Active and Passive SONAR	Gyro turn, straight run, search then home

APPENDIX C

AEGIS PERFORMANCE

This appendix evaluates the saturation level of an AEGIS cruiser to incoming threat missiles. This saturation level was then used to evaluate the performance of the present battle group configuration with and without the CMX present. The assumptions used to develop the time line for the saturation engagement are as follows:

- A maximum of sixteen SM-2 Block 4 missiles are in the air simultaneously.
- All threat missiles are launched simultaneously at maximum range.
- Engagement with SM-2 missiles begins at the maximum range of the SM-2.
- Each threat missile is engaged with two SM-2.
- The launch interval of SM-2 missiles is 1 second.
- The launch interval of 1 second will provide sufficient separation during terminal homing such that no more than four SM-2 missiles will be in terminal homing at the same time.
- There is no fratricide between SM-2s.
- Each SM-2 can only engage one threat missile.
- The probability of kill (Pk) for the SM-2 against any threat missile is 0.7.
- The time interval between SM-2 missile end of flight and launching of another SM-2 is 0.1 seconds.

Takeover and Seagull missiles, as described in Appendix B, were used as the threat missiles for the analysis. Their characteristics are listed in the following table. The time line data is provided at the end of this appendix.

Designated Enemy Missile Name	Radar Cross section (m^2)	Speed (Mach)	Range (nm)	Warhead Weight (kg)	Guidance	Profile Trajectory
Seagull (S-S)	0.11	0.7	15	110	Active Radar	15 meter sea skimmer
Takeover (A-S)	0.7	3.4	300	1000	Active or Passive Radar	High Altitude w/50° terminal dive to target

The results obtained from this analysis are:

- Maximum of thirty-two Takeover missiles may be engaged with 2.9 leaking through to the ship's inner defense zone.
- Maximum of twenty-nine Seagull missiles may be engaged with 2.7 leaking through to the ship's inner defense zone.

Takeover Missile: Mach 3.4 High Altitude w/50 deg Dive

Time (sec)	Horizontal Range (nm)	Altitude (ft)	Slant Range (nm)	SM-2	SM-2 Missiles in the air	Total SM-2 Missiles Launched
480.0	300.2	50,000	300.3	*Missiles Launched*		
400.0	249.5	50,000	249.7			
300.0	186.2	50,000	186.4			
287.0	177.9	50,000	178.1	*Missiles Detected*		
277.0	171.6	50,000	171.8	*Missiles Classified and Assigned to FCS*		
275.0	170.3	50,000	170.5	Launch against Threat #1	1	1
274.0	169.7	50,000	169.9	Launch against Threat #1	2	2
273.0	169.1	50,000	169.3	Launch against Threat #2	3	3
272.0	168.4	50,000	168.6	Launch against Threat #2	4	4
271.0	167.8	50,000	168.0	Launch against Threat #3	5	5
270.0	167.2	50,000	167.4	Launch against Threat #3	6	6
269.0	166.5	50,000	166.7	Launch against Threat #4	7	7
268.0	165.9	50,000	166.1	Launch against Threat #4	8	8
267.0	165.3	50,000	165.5	Launch against Threat #5	9	9
266.0	164.6	50,000	164.8	Launch against Threat #5	10	10
265.0	164.0	50,000	164.2	Launch against Threat #6	11	11
264.0	163.4	50,000	163.6	Launch against Threat #6	12	12
263.0	162.7	50,000	163.0	Launch against Threat #7	13	13
262.0	162.1	50,000	162.3	Launch against Threat #7	14	14
261.0	161.5	50,000	161.7	Launch against Threat #8	15	15
260.0	160.8	50,000	161.1	Launch against Threat #8	16	16
131.6	79.5	50,000	79.9	Threat #1 Hit?	15	
131.5	79.4	50,000	79.9	Launch against Threat #9	16	17
131.2	79.2	50,000	79.6	Threat #1 Hit?	15	
130.7	78.9	50,000	79.3	Threat #2 Hit?	14	
130.5	78.8	50,000	79.2	Launch against Threat #9	15	18
130.2	78.6	50,000	79.1	Threat #2 Hit?	14	
129.8	78.3	50,000	78.8	Threat #3 Hit?	13	
129.5	78.2	50,000	78.6	Launch against Threat #10	14	19
129.3	78.0	50,000	78.5	Threat #3 Hit?	13	
128.8	77.7	50,000	78.2	Threat #4 Hit?	12	
128.5	77.5	50,000	78.0	Launch against Threat #10	13	20
128.3	77.4	50,000	77.8	Threat #4 Hit?	12	
127.9	77.1	50,000	77.6	Threat #5 Hit?	11	
127.5	76.9	50,000	77.3	Launch against Threat #11	12	21
127.4	76.8	50,000	77.3	Threat #5 Hit?	11	
126.9	76.5	50,000	77.0	Threat #6 Hit?	10	
126.5	76.3	50,000	76.7	Launch against Threat #11	11	22
126.4	76.2	50,000	76.7	Threat #6 Hit?	10	
126.0	75.9	50,000	76.4	Threat #7 Hit?	9	
125.5	75.6	50,000	76.1	Threat #7 Hit?	8	
125.5	75.6	50,000	76.1	Launch against Threat #12	9	23

125.0	75.3	50,000	75.8	Threat #8 Hit?	8	
124.6	75.0	50,000	75.5	Threat #8 Hit?	7	
124.5	75.0	50,000	75.5	Launch against Threat #12	8	24
123.5	74.4	50,000	74.8	Launch against Threat #13	9	25
122.5	73.7	50,000	74.2	Launch against Threat #13	10	26
121.5	73.1	50,000	73.6	Launch against Threat #14	11	27
120.5	72.5	50,000	72.9	Launch against Threat #14	12	28
119.5	71.8	50,000	72.3	Launch against Threat #15	13	29
118.5	71.2	50,000	71.7	Launch against Threat #15	14	30
117.5	70.6	50,000	71.0	Launch against Threat #16	15	31
116.5	69.9	50,000	70.4	Launch against Threat #16	16	32
63.7	36.5	50,000	37.4	Threat #9 Hit?	15	
63.6	36.4	50,000	37.3	Launch against Threat #17	16	33
63.3	36.2	50,000	37.1	Threat #9 Hit?	15	
62.8	35.9	50,000	36.8	Threat #10 Hit?	14	
62.6	35.8	50,000	36.7	Launch against Threat #17	15	34
62.3	35.6	50,000	36.5	Threat #10 Hit?	14	
61.8	35.3	50,000	36.3	Threat #11 Hit?	13	
61.6	35.1	50,000	36.1	Launch against Threat #18	14	35
61.3	35.0	50,000	36.0	Threat #11 Hit?	13	
60.9	34.7	50,000	35.7	Threat #12 Hit?	12	
60.6	34.5	50,000	35.5	Launch against Threat #18	13	36
60.4	34.4	50,000	35.4	Threat #12 Hit?	12	
59.9	34.1	50,000	35.1	Threat #13 Hit?	11	
59.6	33.9	50,000	34.9	Launch against Threat #19	12	37
59.4	33.7	50,000	34.8	Threat #13 Hit?	11	
59.0	33.5	50,000	34.5	Threat #14 Hit?	10	
58.6	33.2	50,000	34.3	Launch against Threat #19	11	38
58.5	33.2	50,000	34.2	Threat #14 Hit?	10	
58.0	32.9	50,000	33.9	Threat #15 Hit?	9	
57.6	32.6	50,000	33.7	Launch against Threat #20	10	39
57.5	32.5	50,000	33.6	Threat #15 Hit?	9	
57.0	32.2	50,000	33.3	Threat #16 Hit?	8	
56.6	32.0	50,000	33.0	Launch against Threat #20	9	40
56.5	31.9	50,000	33.0	Threat #16 Hit?	8	
55.6	31.3	50,000	32.4	Launch against Threat #21	9	41
54.6	30.7	50,000	31.8	Launch against Threat #21	10	42
53.6	30.1	50,000	31.2	Launch against Threat #22	11	43
52.6	29.4	50,000	30.6	Launch against Threat #22	12	44
51.6	28.8	50,000	30.0	Launch against Threat #23	13	45
50.6	28.2	50,000	29.4	Launch against Threat #23	14	46
49.6	27.5	50,000	28.8	Launch against Threat #24	15	47
48.6	26.9	50,000	28.2	Launch against Threat #24	16	48
30.4	15.4	50,000	17.5	Threat #17 Hit?	15	
30.3	15.3	50,000	17.4	Launch against Threat #25	16	49
29.9	15.1	50,000	17.2	Threat #17 Hit?	15	
29.4	14.7	50,000	16.9	Threat #18 Hit?	14	

29.3	14.7	50,000	16.9	Launch against Threat #25	15	50
28.9	14.4	50,000	16.6	Threat #18 Hit?	14	
28.3	14.1	50,000	16.4	Threat #19 Hit?	13	
28.3	14.0	50,000	16.3	Launch against Threat #26	14	51
27.8	13.7	50,000	16.1	Threat #19 Hit?	13	
27.3	13.4	50,000	15.8	Launch against Threat #26	14	52
27.3	13.4	50,000	15.8	Threat #20 Hit?	13	
26.7	13.1	50,000	15.5	Threat #20 Hit?	12	
26.3	12.8	50,000	15.3	Launch against Threat #27	13	53
26.2	12.7	50,000	15.2	Threat #21 Hit?	12	
25.7	12.4	50,000	14.9	Threat #21 Hit?	11	
25.3	12.1	50,000	14.7	Launch against Threat #27	12	54
25.1	12.0	50,000	14.6	Threat #22 Hit?	11	
24.6	11.7	50,000	14.3	Threat #22 Hit?	10	
24.3	11.5	50,000	14.2	Launch against Threat #28	11	55
24.0	11.3	50,000	14.1	Threat #23 Hit?	10	
23.4	11.0	50,000	13.8	Threat #23 Hit?	9	
23.3	10.9	50,000	13.7	Launch against Threat #28	10	56
22.9	10.6	50,000	13.5	Threat #24 Hit?	9	
22.3	10.2	50,000	13.2	Threat #24 Hit?	8	
22.3	10.2	50,000	13.2	Launch against Threat #29	9	57
21.3	9.6	50,000	12.7	Launch against Threat #29	10	58
20.3	9.0	50,000	12.2	Launch against Threat #30	11	59
19.3	8.3	50,000	11.8	Launch against Threat #30	12	60
18.3	7.7	50,000	11.4	Launch against Threat #31	13	61
17.3	7.1	50,000	10.9	Launch against Threat #31	14	62
17.2	7.0	50,000	10.9	*Missile Terminal Dive*		
16.3	6.4	50,000	10.5	Launch against Threat #32	15	63
15.3	5.8	50,000	10.2	Launch against Threat #32	16	64
12.9	5.3	37,572	8.2	Threat #25 Hit?	15	
12.5	5.1	36,378	7.9	Threat #25 Hit?	14	
12.1	4.9	35,185	7.7	Threat #26 Hit?	13	
11.7	4.8	34,021	7.4	Threat #26 Hit?	12	
11.3	4.6	32,886	7.2	Threat #27 Hit?	11	
10.9	4.4	31,751	6.9	Threat #27 Hit?	10	
10.5	4.3	30,645	6.7	Threat #28 Hit?	9	
10.1	4.1	29,539	6.4	Threat #28 Hit?	8	
9.8	4.0	28,463	6.2	Threat #29 Hit?	7	
9.4	3.8	27,444	6.0	Threat #29 Hit?	6	
9.1	3.7	26,396	5.7	Threat #30 Hit?	5	
8.7	3.5	25,407	5.5	Threat #30 Hit?	4	
8.4	3.4	24,476	5.3	Threat #31 Hit?	3	
8.1	3.3	23,574	5.1	Threat #31 Hit?	2	
7.8	3.2	22,701	4.9	Threat #32 Hit?	1	
7.5	3.1	21,915	4.8	Threat #32 Hit?	0	
0.0	0.0	30	0.0			

Each incoming missile is engaged by 2 SM-2 Blk 4 missiles
Each SM-2 has a Pk of 0.7
Incoming missile raid size is 32 missiles per ship
Pk for each incoming missile is 0.91
# of leakers is 0.09x32=2.88 missiles

Seagull Missile: Mach 0.7 15 meter Sea Skimmer

Time (sec)	Horizontal Range (nm)	Altitude (ft)	Slant Range (nm)	SM-2	SM-2 Missiles in the air	Total SM-2 Missiles Launched
115.0	15.0	45.0	15.0	*Missiles Launched*		
110.0	14.3	45.0	14.3	*Missiles Detected*		
100.0	13.0	45.0	13.0	*Missiles Classified and Assigned to FCS*		
98.0	12.8	45.0	12.8	Launch against Threat #1	1	1
97.0	12.7	45.0	12.7	Launch against Threat #1	2	2
96.0	12.5	45.0	12.5	Launch against Threat #2	3	3
95.0	12.4	45.0	12.4	Launch against Threat #2	4	4
94.0	12.3	45.0	12.3	Launch against Threat #3	5	5
93.0	12.1	45.0	12.1	Launch against Threat #3	6	6
92.0	12.0	45.0	12.0	Launch against Threat #4	7	7
91.0	11.9	45.0	11.9	Launch against Threat #4	8	8
90.0	11.7	45.0	11.7	Launch against Threat #5	9	9
89.0	11.6	45.0	11.6	Launch against Threat #5	10	10
88.0	11.5	45.0	11.5	Launch against Threat #6	11	11
87.0	11.3	45.0	11.3	Launch against Threat #6	12	12
86.0	11.2	45.0	11.2	Launch against Threat #7	13	13
85.0	11.1	45.0	11.1	Launch against Threat #7	14	14
84.0	11.0	45.0	11.0	Launch against Threat #8	15	15
83.0	10.8	45.0	10.8	Launch against Threat #8	16	16
79.5	10.4	45.0	10.4	Threat #1 Hit?	15	
79.4	10.4	45.0	10.4	Launch against Threat #9	16	17
78.7	10.3	45.0	10.3	Threat #1 Hit?	15	
78.4	10.2	45.0	10.2	Launch against Threat #9	16	18
77.8	10.2	45.0	10.2	Threat #2 Hit?	15	
77.4	10.1	45.0	10.1	Launch against Threat #10	16	19
77.0	10.0	45.0	10.0	Threat #2 Hit?	15	
76.4	10.0	45.0	10.0	Launch against Threat #10	16	20
76.2	9.9	45.0	9.9	Threat #3 Hit?	15	
75.4	9.8	45.0	9.8	Threat #3 Hit?	14	
75.4	9.8	45.0	9.8	Launch against Threat #11	15	21
74.6	9.7	45.0	9.7	Threat #4 Hit?	14	
74.4	9.7	45.0	9.7	Launch against Threat #11	15	22
73.8	9.6	45.0	9.6	Threat #4 Hit?	14	
73.4	9.6	45.0	9.6	Launch against Threat #12	15	23
73.0	9.5	45.0	9.5	Threat #5 Hit?	14	
72.4	9.4	45.0	9.4	Launch against Threat #12	15	24
72.2	9.4	45.0	9.4	Threat #5 Hit?	14	
71.4	9.3	45.0	9.3	Launch against Threat #13	15	25
71.4	9.3	45.0	9.3	Threat #6 Hit?	14	
70.5	9.2	45.0	9.2	Threat #6 Hit?	13	
70.4	9.2	45.0	9.2	Launch against Threat #13	14	26
69.7	9.1	45.0	9.1	Threat #7 Hit?	13	

69.4	9.1	45.0	9.1	Launch against Threat #14	14	27
68.9	9.0	45.0	9.0	Threat #7 Hit?	13	
68.4	8.9	45.0	8.9	Launch against Threat #14	14	28
68.1	8.9	45.0	8.9	Threat #8 Hit?	13	
67.4	8.8	45.0	8.8	Launch against Threat #15	14	29
67.3	8.8	45.0	8.8	Threat #8 Hit?	13	
66.4	8.7	45.0	8.7	Launch against Threat #15	14	30
65.4	8.5	45.0	8.5	Launch against Threat #16	15	31
64.4	8.4	45.0	8.4	Launch against Threat #16	16	32
64.4	8.4	45.0	8.4	Threat #9 Hit?	15	
63.6	8.3	45.0	8.3	Threat #9 Hit?	14	
63.4	8.3	45.0	8.3	Launch against Threat #17	15	33
62.7	8.2	45.0	8.2	Threat #10 Hit?	14	
62.4	8.1	45.0	8.1	Launch against Threat #17	15	34
61.9	8.1	45.0	8.1	Threat #10Hit?	14	
61.4	8.0	45.0	8.0	Launch against Threat #18	15	35
61.1	8.0	45.0	8.0	Threat #11 Hit?	14	
60.4	7.9	45.0	7.9	Launch against Threat #18	15	36
60.3	7.9	45.0	7.9	Threat #11 Hit?	14	
59.5	7.8	45.0	7.8	Threat #12 Hit?	13	
59.4	7.7	45.0	7.7	Launch against Threat #19	14	37
58.7	7.7	45.0	7.7	Threat #12 Hit?	13	
58.4	7.6	45.0	7.6	Launch against Threat #19	14	38
57.9	7.6	45.0	7.6	Threat #13 Hit?	13	
57.4	7.5	45.0	7.5	Launch against Threat #20	14	39
57.1	7.4	45.0	7.4	Threat #13 Hit?	13	
56.4	7.4	45.0	7.4	Launch against Threat #20	14	40
56.3	7.3	45.0	7.3	Threat #14 Hit?	13	
55.5	7.2	45.0	7.2	Threat #14 Hit?	12	
55.4	7.2	45.0	7.2	Launch against Threat #21	13	41
54.7	7.1	45.0	7.1	Threat #15 Hit?	12	
54.4	7.1	45.0	7.1	Launch against Threat #21	13	42
53.8	7.0	45.0	7.0	Threat #15 Hit?	12	
53.4	7.0	45.0	7.0	Launch against Threat #22	13	43
53.0	6.9	45.0	6.9	Threat #16 Hit?	12	
52.4	6.8	45.0	6.8	Launch against Threat #22	13	44
52.2	6.8	45.0	6.8	Threat #16 Hit?	12	
51.4	6.7	45.0	6.7	Threat #17 Hit?	11	
51.4	6.7	45.0	6.7	Launch against Threat #23	12	45
50.6	6.6	45.0	6.6	Threat #17 Hit?	11	
50.4	6.6	45.0	6.6	Launch against Threat #23	12	46
49.8	6.5	45.0	6.5	Threat #18 Hit?	11	
49.4	6.4	45.0	6.4	Launch against Threat #24	12	47
49.0	6.4	45.0	6.4	Threat #18 Hit?	11	
48.4	6.3	45.0	6.3	Launch against Threat #24	12	48
48.2	6.3	45.0	6.3	Threat #19 Hit?	11	
47.4	6.2	45.0	6.2	Launch against Threat #25	12	49

47.4	6.2	45.0	6.2	Threat #19 Hit?	11	
46.5	6.1	45.0	6.1	Threat #20 Hit?	10	
46.4	6.1	45.0	6.1	Launch against Threat #25	11	50
45.7	6.0	45.0	6.0	Threat #20 Hit?	10	
45.4	5.9	45.0	5.9	Launch against Threat #26	11	51
44.9	5.9	45.0	5.9	Threat #21 Hit?	10	
44.4	5.8	45.0	5.8	Launch against Threat #26	11	52
44.1	5.8	45.0	5.8	Threat #21 Hit?	10	
43.4	5.7	45.0	5.7	Launch against Threat #27	11	53
43.3	5.6	45.0	5.6	Threat #22 Hit?	10	
42.5	5.5	45.0	5.5	Threat #22 Hit?	9	
42.4	5.5	45.0	5.5	Launch against Threat #27	10	54
41.7	5.4	45.0	5.4	Threat #23 Hit?	9	
41.4	5.4	45.0	5.4	Launch against Threat #28	10	55
40.9	5.3	45.0	5.3	Threat #23 Hit?	9	
40.4	5.3	45.0	5.3	Launch against Threat #28	10	56
40.1	5.2	45.0	5.2	Threat #24 Hit?	9	
39.4	5.1	45.0	5.1	Launch against Threat #29	10	57
39.2	5.1	45.0	5.1	Threat #24 Hit?	9	
38.4	5.0	45.0	5.0	Threat #25 Hit?	8	
38.4	5.0	45.0	5.0	Launch against Threat #29	9	58
37.6	4.9	45.0	4.9	Threat #25 Hit?	8	
36.8	4.8	45.0	4.8	Threat #26 Hit?	7	
36.0	4.7	45.0	4.7	Threat #26 Hit?	6	
35.2	4.6	45.0	4.6	Threat #27 Hit?	5	
34.4	4.5	45.0	4.5	Threat #27 Hit?	4	
33.6	4.4	45.0	4.4	Threat #28 Hit?	3	
32.8	4.3	45.0	4.3	Threat #28 Hit?	2	
32.0	4.2	45.0	4.2	Threat #29 Hit?	1	
31.2	4.1	45.0	4.1	Threat #29 Hit?	0	
0.0	0.0	30.0	0.0			

Each incoming missile is engaged by 2 SM-2 Blk 4 missiles
Each SM-2 has a Pk of 0.7
Incoming raid size is 29 missiles per ship
Pk for each incoming missiile is 0.91
# of leakers is 0.09x29=2.61 missiles

APPENDIX D

ROUGH ORDER OF MAGNITUDE (ROM) STUDIES

Rough Order of Magnitude (ROM) studies provided the basis for the selection of ship performance requirements. In this context, "rough" order of magnitude indicates a general degree of reasonableness. The results of the ROM studies were combined with engineering judgment, system engineering concepts and design team discussion (and debate) to produce a first draft of realistic requirements for the Operational Requirements Document (ORD).

Computer programs, developed by Decision Engineering Company for Dr. Dean Rains, facilitated the ROM studies. The Decision Engineering cruiser and destroyer modeling program, "SHIP" is written in program modules using the Basic computer language and runs on an IBM PC compatible computer. SHIP incorporates polynomial models for various propulsion, auxiliary and combat systems for hull sizes and hull forms based on modern cruisers and destroyers. SHIP can accurately model the Spruance class destroyer (DD 963), the Ticonderoga class cruiser (from CG 52 onward) and the Arleigh Burke class guided missile destroyer (DDG 51). The program includes models for new technologies ranging from planetary main reduction gears to integrated electric drive with pods. The program contains affordability analysis modules and can provide acquisition cost estimates based on production factors and projected life cycle. Basic naval architecture and hydrodynamic parameters are included in the computer analysis. In summary, to support the ROM studies, the program provided a non-graphical, first order description of a cruiser or destroyer type ship with specific machinery and combat systems arrangements.

A. SHIP MODELS

The design team analyzed a three ship subset of the six CMX variants which were used for the evaluation scenarios. The CMX ships modeled for ROM studies included the CMX v3 with 3 VLS, the CMX v4 with 4 VLS, and the CMX v6 with 6 VLS. This selection was based primarily on time and data base constraints. The initial hull form for all ship models was a DDG/DDV with a higher length to beam ratio in order to accommodate additional VLS installations. All ship models used the following systems, subsystems or equipments:

- LM2500-30 gas turbine prime movers for main propulsion
- Vertical exhaust stacks with eductors for reduced IR signatures
- Stern wedges for hydrodynamic efficiency
- CRP propellers
- Fiberoptic data bus with multiplexing
- Reduced manning concepts (75% of nominal)
- 1 helicopter and hangar
- MK 49 (mod) 2-D air search radar
- Small, self-defense AAW missiles in VLS
- 2 CIWS
- No sonar system

Six additional systems and technologies were modeled on an incremental basis. These technologies included: 1) baseline run, 2) reduced radar cross section by sloping sides and adding radar absorbing material (RAM) to eductors/stacks, 3) composite shafting and Graphite

Reinforced (GRP) auxiliary piping, 4) zonal/bilevel auxiliaries with small diesel generators, 5) composite deckhouse and 6) a cross-connect gear box and planetary main reduction gears. It is emphasized that these models were incremental in that the new system or technology was added to the previous model. For example, model v3-4 incorporates the systems and technologies for models v3-1, v3-2, v3-3 and v3-4. Program results are illustrated in the following tables:

CMX v3 Models

		v3-1	v3-2	v3-3	v3-4	v3-5	v3-6
Cost	**$ M**	517	518	509	481	478	471
Displacement	**tons**	6890	6901	6620	5976	5893	5522
Volume	**ft^3**	729000	729000	721000	632000	631000	602000
Length	**ft**	537	538	530	512	510	499
Beam	**ft**	59.7	59.7	58.9	56.9	56.7	55.5
Draft	**ft**	17.4	17.4	17.2	16.6	16.5	16.2
Freeboard	**ft**	15.6	15.6	16.1	14.9	15.1	15.2
Range	**nm**	6000	6000	6000	6000	6000	6000
Vc	**knots**	20	20	20	20	20	20
Vss	**knots**	26	26	26	26	26	26
Vmax	**knots**	29.7	29.7	29.8	30.3	30.4	30.6
Shafts		2	2	2	2	2	2
Engines		2	2	2	2	2	2
Crew Size		189	189	184	174	174	167
Electric Pwr	**kw**	7500	7500	7500	6300	6300	5600
HVAC	**tons**	520	521	519	510	510	506

CMX v4 Models							
		v4-1	v4-2	v4-3	v4-4	v4-5	v4-6
Cost	$ M	551	552	542	514	511	505
Displacement	tons	7259	7272	6970	6324	6242	5867
Volume	ft^3	767000	768000	757000	666000	665000	636000
Length	ft	547	547	539	522	520	509
Beam	ft	60.8	60.8	59.9	58	57.8	56.6
Draft	ft	17.7	17.7	17.5	16.9	16.8	16.5
Freeboard	ft	15.8	15.8	16.3	15	15.3	15.4
Range	nm	6000	6000	6000	6000	6000	6000
Vc	knots	20	20	20	20	20	20
Vss	knots	26	26	26	26	26	26
Vmax	knots	29.5	29.5	29.6	30.1	30.1	30.4
Shafts		2	2	2	2	2	2
Engines		2	2	2	2	2	2
Crew Size		195	196	189	178	178	171
Electric Pwr	kw	7500	7500	7500	6300	6300	5600
HVAC	tons	525	525	522	514	513	510

Incremental models one through six were also run for CMX v6. A seventh model with a flat top deck and additional RAM, and an eighth model with a double hull were run. These additional runs were selected to demonstrate further cost reduction through configuration and technology selection. With CMX v3-1 through -6 , CMX v4-1 through -6 and CMX v6-1 through -8 demonstrated as reasonable missile carriers, the goal of the studies was directed toward the effect of cruising range, sustained speed, number of shafts and so forth. These parameters varied for CMX v6-8, and are identified by an alphabet letter following v6-8, e.g.., CMX v6-8f Then, additional parameters were varied on CMX v6-8k. The v6-8k models are labeled CMX-v6-8k where the additional alphabet letter before the '8' identifies the run.

CMX v6 Models									
		v6-1	v6-2	v6-3	v6-4	v6-5	v6-6	v6-7	v6-8
Cost	$ M	616	617	608	581	578	572	573	575
Displacement	tons	7889	7898	7612	6989	6891	6510	6543	6659
Volume	ft^3	831000	831000	825000	731000	729000	699000	705289	707614
Length	ft	562	562	555	522	537	527	528	531
Beam	ft	62.5	62.5	61.7	60	59.7	58.6	58.7	59
Draft	ft	18.2	17.7	18	17.5	17.4	17.1	17.1	17.2
Freeboard	ft	16.2	16.2	16.8	15.4	15.7	15.7	15.8	15.5
Range	nm	6000	6000	6000	6000	6000	6000	6000	6000
Vc	knots	20	20	20	20	20	20	20	20
Vss	knots	26	26	26	26	26	26	26	26
Vmax	knots	29.1	29.1	29.2	29.6	29.7	29.9	29.9	29.8
Shafts		2	2	2	2	2	2	2	2
Engines		2	2	2	2	2	2	2	2
Crew Size		198	198	195	181	178	174	175	177
Electric Pwr	kw	7500	7500	7500	7000	7000	6300	6300	6300
HVAC	tons	531	531	530	521	520	516	517	518

Varied Parameters for CMX v6-8 Model									
		v6-8b	v6-8c	v6-8f	v6-8g	v6-8h	v6-8i	v6-8j	v6-8k
Cost	**$ M**	582	575	554	566	566	568	607	572
Displacement	**tons**	7196	6658	6206	6529	6529	6777	7593	7057
Volume	**ft^3**	747000	708000	656000	680000	680000	696000	788000	718000
Length	**ft**	545	531	519	528	528	534	555	542
Beam	**ft**	60.6	59	57.7	58.6	58.6	59.4	61.7	60.2
Draft	**ft**	17.7	17.2	16.8	17.1	17.1	17.3	18	17.5
Freeboard	**ft**	15.4	15.5	15.1	14.9	14.9	14.8	15.6	14.7
Range	**nm**	8000	6000	6000	6000	6000	7000	8000	8000
Vc	**knots**	20	20	20	20	20	20	20	20
Vss	**knots**	26	28	25	20	28	28	28	26
Vmax	**knots**	29.5	29.8	27.3	29.9	29.9	29.8	32.4	29.5
Shafts		2	2	2	1	1	1	1	1
Engines		2	2	2*	2	2	2	3	2
Crew Size		189	177	170	175	175	179	195	187
Electric Pwr	**kw**	6300	6300	6300	6300	6300	6300	7000	6300
HVAC	**tons**	523	518	512	515	515	518	527	520

* indicates LM1600 gas turbines

Additional Variations for Model CMX v6-8k								
		v6-a8k	v6-b8k	v6-c8k	v6-d8k	v6-e8k	v6-f8k	v6-g8k
Cost	$ M	572	596	578	594	595	589	574
Displacement	tons	7057	7941	7529	7923	7766	7769	7294
Volume	ft^3	718000	834000	793000	833000	829000	829000	743000
Length	ft	542	563	553	563	559	559	548
Beam	ft	60.2	62.6	61.5	62.5	62.1	62.1	60.8
Draft	ft	17.5	18.3	17.9	18.2	18.1	18.1	17.7
Freeboard	ft	14.7	16.2	15.9	16.2	16.5	16.5	14.9
Range	nm	8000	8000	8000	8000	8000	8000	8000
Vc	knots	20	20	20	20	20	20	20
Vss	knots	27	27	27	27	27	27	27
Vmax	knots	29.5	29.1	28.7	29.1	29.1	29.1	29.5
Shafts		1	1	1	1	1	1	1
Engines		2	2	2	2	2	2	2
Crew Size		187	201	195	200	198	198	190
Electric Pwr	kw	6300	7000	PDSS	7000	7000	7000	6300
HVAC	tons	520	531	527	531	530	530	523

B. SHIP PERFORMANCE REQUIREMENTS

The preceding analysis indicated a range of desirable performance characteristics based on existing or developing technology, which is achievable at a reasonable cost. These results provided a basis for the first draft of the ORD. These results further supported choices for the feasibility studies which were performed using ASSET computer software.

APPENDIX E

THREAT ENGAGEMENT PROFILES

The threat engagement profiles are presented in the following tables. Shown are the timelines for the CMX combat system engagements of the Trasher, Takeover, Sunstroke and Seagull missiles.

Trasher Missile: Mach 2.5 Anti-Radiation

Time (sec)	Horizontal Range (nm)	Altitude (ft)	Slant Range (nm)	Sea Sparrow	CIWS	EW/Chaff	Incremental Kill Probability	Cumulative Kill Probability
85.9	40.0	5,000.0	40.0	*Missile Launched*				
80.0	37.3	4,660.3	37.3	*Missile Detected*				
70.0	32.6	4,081.5	32.6	*Missile Classified as Threat and Assigned toFCS*				
60.0	27.9	3,502.7	28.0			Engage	0.1	0.1
50.0	23.3	2,923.9	23.3					
46.0	21.4	2,692.4	21.4	Launch				
45.0	21.0	2,634.5	21.0	Launch				
40.0	18.6	2,345.1	18.6					
30.0	14.0	1,766.3	14.0					
20.0	9.3	1,187.6	9.3					
19.0	8.8	1,129.7	8.9					
18.0	8.4	1,071.8	8.4					
17.3	8.0	1,028.4	8.0	Hit?			0.7	0.73
17.0	7.9	1,013.9	7.9					
16.9	16.9	1,008.1	7.9	Hit?			0.7	0.919
16.0	7.5	956.1	7.5					
15.0	7.0	898.2	7.0					
14.0	6.5	840.3	6.5					
13.0	6.1	782.4	6.1					
12.0	5.6	724.5	5.6	Launch				
11.0	5.1	666.7	5.1	Launch				
10.0	4.7	608.8	4.7					
9.0	4.2	550.9	4.2					
8.0	3.7	493.0	3.7					
7.0	3.3	435.1	3.3					
6.0	2.8	377.3	2.8					
5.0	2.3	319.4	2.3					
4.5	2.1	290.5	2.1	Hit?			0.7	0.9757
4.1	1.9	269.0	1.9	Hit?			0.7	0.99271
4.0	1.9	261.5	1.9					
3.0	1.4	203.6	1.4					
2.0	0.9	145.8	0.9					
1.8	0.8	134.2	0.8		Engage		0.3	0.994897
1.0	0.5	87.9	0.5					
0.0	0.0	30.0	0.0					

Takeover Missile: Mach 3.4 High Altitude w/50 deg Dive

Time (sec)	Horizontal Range (nm)	Altitude (ft)	Slant Range (nm)	Sea Sparrow	CIWS	EW/Chaff	Incremental Kill Probability	Cumulative Kill Probability
480.0	300.2	50,000	300.3	*Missile Launched*				
400.0	249.5	50,000	249.7					
300.0	186.2	50,000	186.4					
200.0	122.8	50,000	123.1					
100.0	59.5	50,000	60.0					
90.0	53.1	50,000	53.8					
84.0	49.3	50,000	50.0	*Missile Detected*				
80.0	46.8	50,000	47.5					
74.0	43.0	50,000	43.8	*Missile Classified and Assigned to FCS*				
72.0	41.7	50,000	42.6			Engage	0.4	0.4
60.0	34.1	50,000	35.1					
50.0	27.8	50,000	29.0					
40.0	21.5	50,000	23.0					
30.0	15.1	50,000	17.3					
20.0	8.8	50,000	12.1					
19.0	8.2	50,000	11.7					
18.0	7.5	50,000	11.2					
17.2	7.0	50,000	10.9	*Missile Terminal Dive*				
17.0	6.9	49,504	10.8					
16.0	6.5	46,593	10.1					
15.0	6.1	43,683	9.5					
14.0	5.7	40,773	8.9	Launch				
13.0	5.3	37,863	8.2	Launch				
12.0	4.9	34,952	7.6					
11.0	4.5	32,042	7.0					
11.0	4.5	32,042	7.0					
10.0	4.1	29,132	6.3					
9.0	3.7	26,222	5.7					
8.0	3.3	23,312	5.1					
7.0	2.8	20,401	4.4					
6.0	2.4	17,491	3.8					
5.0	2.0	14,581	3.2					
4.3	1.7	12,515	2.7	Hit?			0.8	0.88
4.0	1.6	11,613	2.5	Hit?			0.8	0.976
3.0	1.2	8,761	1.9					
2.0	0.8	5,850	1.3					
1.3	0.5	3,813	0.8		Engage		0.8	0.9952
1.0	0.4	2,940	0.6					
0.0	0.0	30	0.0					

Sunstroke Missile: Mach 2.5 10 Meter Sea Skimmer

Time (sec)	Horizontal Range (nm)	Altitude (ft)	Slant Range (nm)	Sea Sparrow	CIWS	EW/Chaff	Incremental Kill Probability	Cumulative Kill Probability
140.0	65.2	30.0	65.2	*Missile Launched*				
120.0	55.9	30.0	55.9					
110.0	51.2	30.0	51.2					
100.0	46.6	30.0	46.6					
90.0	41.9	30.0	41.9					
80.0	37.3	30.0	37.3					
70.0	32.6	30.0	32.6					
60.0	28.0	30.0	28.0					
50.0	23.3	30.0	23.3					
40.0	18.6	30.0	18.6					
32.0	14.9	30.0	14.9	*Missile Detected*				
30.0	14.0	30.0	14.0					
22.0	10.2	30.0	10.2	*Missile Classified as Threat and Assigned to FCS*				
20.0	9.3	30.0	9.3	Launch		Engage	0.4	0.4
19.0	8.9	30.0	8.9	Launch				
18.0	8.4	30.0	8.4					
17.0	7.9	30.0	7.9					
16.0	7.5	30.0	7.5					
15.0	7.0	30.0	7.0					
14.0	6.5	30.0	6.5					
13.0	6.1	30.0	6.1					
12.0	5.6	30.0	5.6					
11.0	5.1	30.0	5.1					
10.0	4.7	30.0	4.7					
9.0	4.2	30.0	4.2					
8.0	3.7	30.0	3.7					
7.5	3.5	30.0	3.5	Hit?			0.6	0.76
7.1	3.3	30.0	3.3	Hit?			0.6	0.904
7.0	3.3	30.0	3.3					
6.0	2.8	30.0	2.8					
5.0	2.3	30.0	2.3					
4.0	1.9	30.0	1.9					
3.0	1.4	30.0	1.4					
2.0	0.9	30.0	0.9					
1.7	0.8	30.0	0.8		Engage		0.5	0.952
1.0	0.5	30.0	0.5					
0.0	0.0	30.0	0.0					

Seagull Missile: Mach 0.7 15 meter Sea Skimmer

Time (sec)	Horizontal Range (nm)	Altitude (ft)	Slant Range (nm)	Sea Sparrow	CIWS	EW/Chaff	Incremental Kill Probability	Cumulative Kill Probability
115.0	15.0	45.0	15.0	*Missile Launched*				
110.0	14.3	45.0	14.3	*Missile Detected*				
100.0	13.0	45.0	13.0	*Missile Classified As Threat and Assigned to FCS*				
90.0	11.7	45.0	11.7	Launch		Engage	0.4	0.4
89.0	11.6	45.0	11.6	Launch				
80.0	10.4	45.0	10.4					
70.0	9.1	45.0	9.1					
61.3	8.0	45.0	8.0	Hit?			0.7	0.82
60.7	7.9	45.0	7.9	Hit?			0.7	0.946
60.0	7.8	45.0	7.8					
56.0	7.3	45.0	7.3	Launch				
55.0	7.2	45.0	7.2	Launch				
50.0	6.5	45.0	6.5					
40.0	5.2	45.0	5.2					
38.2	5.0	45.0	5.0	Hit?			0.7	0.9838
37.5	4.9	45.0	4.9	Hit?			0.7	0.99514
33.0	4.3	45.0	4.3	Launch				
32.0	4.2	45.0	4.2	Launch				
30.0	3.9	45.0	3.9					
22.5	2.9	45.0	2.9	Hit?			0.7	0.998542
21.8	2.8	45.0	2.8	Hit?			0.7	0.9995626
20.0	2.6	45.0	2.6					
16.0	2.1	45.0	2.1	Launch				
15.0	2.0	45.0	2.0	Launch				
10.9	1.4	41.0	1.4	Hit?			0.7	0.99986878
10.2	1.3	40.0	1.3	Hit?			0.7	0.999960634
10.0	1.3	35.0	1.3					
9.0	1.2	34.0	1.2					
8.0	1.0	33.0	1.0					
7.0	0.9	32.0	0.9					
6.3	0.8	31.0	0.8		Engage		0.7	0.9999881902
6.0	0.8	31.0	0.8					
5.0	0.7	30.0	0.7					
4.0	0.5	30.0	0.5					
3.0	0.4	30.0	0.4					
2.0	0.3	30.0	0.3					
1.0	0.1	30.0	0.1					
0.0	0.0	30.0	0.0					

APPENDIX F

CMX ASSET REPORT

ASSET/MONOSC VERSION 3.2 OUTPUTS

1. DESIGN SUMMARY

SHIP COMMENT TABLE

FINAL VERSION OF CMX (I HOPE) BASED ON CMX3 WITH:
ELECTRIC POD PROPULSION WITH VSCF AND SEPERATE SS GENERATORS;
ELECTRIC HEAT VICE WASTE HEAT BOILERS;
SOLVED TO ACHIEVE 8000 NM ENDURANCE @ 20 KTS;
MARGINS AGREED TO IN CLASS ON (9/93);
USED A COMBINATION OF GEOSIM AND DDG-51 BC'S TO ACHIEVE HULL FORM;
TWO SEPARATE DECK HOUSES (FORE AND AFT);
PAYLOADS TO SUPPORT 6 VLS BANKS (384 CELLS);
NON-SUPERCONDUCTING ELECTRIC PROPULSION MOTORS

PRINCIPAL CHARACTERISTICS - FT	
LBP	577.7
LOA	607.4
BEAM, DWL	57.2
BEAM, WEATHER DECK	65.6
DEPTH @ STA 10	43.1
DRAFT TO KEEL DWL	19.1
DRAFT TO KEEL LWL	19.1
FREEBOARD @ STA 3	33.2
GMT	2.9
CP	0.559
CX	0.818

SPEED(KT): MAX= 30.3 SUST= 28.8
ENDURANCE: 8000.0 NM AT 20.0 KTS

TRANSMISSION TYPE: ELECT
MAIN ENG: 2 RGT @ 26400.0 HP

SHAFT POWER/SHAFT: 21949.7 HP
PROPELLERS: 2 - CR - 14.9 FT DIA

SEP GEN: 1 GT @ 3000.0 KW
PD GEN: 2 VSCF @ 3000.0 KW

24 HR LOAD 2343.2
MAX MARG ELECT LOAD 4706.1

	OFF	CPO	ENL	TOTAL
MANNING	17	15	150	182
ACCOM	19	17	165	201

WEIGHT SUMMARY - LTON	
GROUP 1 - HULL STRUCTURE	3402.0
GROUP 2 - PROP PLANT	393.3
GROUP 3 - ELECT PLANT	263.4
GROUP 4 - COMM + SURVEIL	179.1
GROUP 5 - AUX SYSTEMS	887.0
GROUP 6 - OUTFIT + FURN	510.2
GROUP 7 - ARMAMENT	912.0
SUM GROUPS 1-7	6546.9
DESIGN MARGIN	0.0
LIGHTSHIP WEIGHT	6546.9
LOADS	1869.9
FULL LOAD DISPLACEMENT	8416.8
FULL LOAD KG: FT	26.5

MILITARY PAYLOAD WT - LTON 1798.3
USABLE FUEL WT - LTON 1052.7

AREA SUMMARY - FT2	
HULL AREA -	78264.2
SUPERSTRUCTURE AREA -	11327.6
TOTAL AREA	89591.8

VOLUME SUMMARY - FT3	
HULL VOLUME -	1033448.2
SUPERSTRUCTURE VOLUME -	116073.5
TOTAL VOLUME	1149521.6

2. HULL GEOMETRY SUMMARY

HULL OFFSETS IND-GIVEN		MIN BEAM, FT	30.00
HULL DIM IND-GEOSIM		MAX BEAM, FT	110.00
MARGIN LINE IND-CALC		HULL FLARE ANGLE, DEG	
HULL STA IND-OPTIMUM		FORWARD BULWARK, FT	4.00
HULL BC IND-DDG 51			

HULL PRINCIPAL DIMENSIONS (ON DWL)

LBP, FT	577.65	PRISMATIC COEF	0.559
LOA, FT	607.37	MAX SECTION COEF	0.818
BEAM, FT	57.17	WATERPLANE COEF	0.763
BEAM @ WEATHER DECK, FT	65.64	LCB/LCP	0.506
DRAFT, FT	19.11	HALF SIDING WIDTH, FT	1.00
DEPTH STA 0, FT	52.70	BOT RAKE, FT	0.00
DEPTH STA 3, FT	48.31	RAISED DECK HT, FT	9.03
DEPTH STA 10, FT	43.12	RAISED DECK FWD LIM, STA	
DEPTH STA 20, FT	39.00	RAISED DECK AFT LIM, STA	17.00
FREEBOARD @ STA 3, FT	33.19	BARE HULL DISPL, LTON	8249.94
STABILITY BEAM, FT	57.19	AREA BEAM, FT	47.52

BARE HULL DATA ON LWL		STABILITY DATA ON LWL	
LGTH ON WL, FT	577.63	KB, FT	11.79
BEAM, FT	57.16	BMT, FT	17.70
DRAFT, FT	19.07	KG, FT	26.53
FREEBOARD @ STA 3, FT	33.23	FREE SURF COR, FT	0.10
PRISMATIC COEF	0.559	SERV LIFE KG ALW, FT	0.00
MAX SECTION COEF	0.817		
WATERPLANE COEF	0.762	GMT, FT	2.86
WATERPLANE AREA, FT2	25168.26	GML, FT	1659.15
WETTED SURFACE, FT2	33927.62	GMT/B AVAIL	0.050
		GMT/B REQ	0.050
BARE HULL DISPL, LTON	8225.13		
APPENDAGE DISPL, LTON	191.72		
FULL LOAD WT, LTON	8416.77		

3. HULL SUBDISVISION MODULE SUMMARY

HULL SUBDIV IND-GIVEN		INNER BOT IND-PRESENT	
SHAFT SUPPORT TYPE IND-POD			
LBP, FT	577.65	HULL AVG DECK HT, FT	11.17
DEPTH STA 10, FT	43.		
		NO INTERNAL DECKS	3
HULL VOLUME, FT3	1033448.	NO TRANS BHDS	14
MR VOLUME, FT3	91346.	NO LONG BHDS	0
TANKAGE VOL REQ, FT3	52129.	NO MACHY RMS	4
EXCESS TANKAGE, FT3	11321.	NO PROP SHAFTS	2
ARR AREA LOST TANKS, FT2	41.1		
HULL ARR AREA AVAIL, FT2	78264.2		

4. DECKHOUSE MODULE SUMMARY

DKHS GEOM IND-GIVEN
DKHS SIZE IND-
DKHS MTRL TYPE IND-MS

BLAST RESIST IND-7 PSI
FIRE PROTECT IND-NONE

LBP, FT	577.65	DKHS LENGTH OA, FT	339.06
BEAM, FT	57.17	DKHS MAX WIDTH, FT	53.52
AREA BEAM, FT	47.52	DKHS HT (W/O PLTHS), FT	65.86
DKHS FWD LIMIT-	STA 5.3	OTHER ARR AREA REQ, FT2	66208.12
DKHS AFT LIMIT-	STA 17.0	HULL ARR AREA AVAIL, FT2	78264.20
DKHS AVG DECK HT, FT	10.00	DKHS ARR AREA REQ, FT2	7295.66
DKHS NO LVLS		HANGER ARR AREA REQ, FT2	0.00
DKHS AVG SIDE CLR, FT		PLTHS ARR AREA REQ, FT2	0.00
DKHS AVG SIDE ANG, DEG			
DKHS NO PRISMS	5	DKHS MAX ARR AREA, FT2	11327.63
DKHS ARR AREA DERIV, FT2	297.34	DKHS ARR AREA AVAIL, FT2	11327.63
DKHS MIN ALW BEAM, FT	30.17	DKHS VOLUME, FT3	116073.48
BRIDGE L-O-S OVER BOW, FT	393.21		
		DKHS WEIGHT, LTON	223.10
DKHS SIDE CLR OFFSET, FT		DKHS VCG, FT	55.48
DKHS SIDE ANG OFFSET, DEG			
DKHS DECK HT OFFSET, FT			

5. SUPERSTRUCTURE DECKHOUSE DATA SUMMARY

NO OF SS DECKHOUSE BLKS	5
DKHS VOLUME, FT3	116073.
DKHS ARR AREA AVAIL, FT2	11327.6

	DECKHOUSE NUMBER				
	1	2	3	4	5
DIST FROM BOW, FT	151.92	151.92	151.92	427.46	427.46
LENGTH, FT	57.77	57.77	20.22	63.52	63.52
DIST FROM CL, FT					
FWD/PORT/BTM	-26.76	-25.00	-17.23	-22.64	-20.88
AFT/PORT/BTM	-26.90	-25.14	-17.42	-21.00	-19.24
FWD/STBD/BTM	26.76	25.00	17.23	22.64	20.88
AFT/STBD/BTM	26.90	25.14	17.42	21.00	19.24
FWD/PORT/TOP	-25.00	-23.23	-15.47	-20.88	-19.12
AFT/PORT/TOP	-25.14	-23.38	-15.66	-19.24	-17.47
FWD/STBD/TOP	25.00	23.23	15.47	20.88	19.12
AFT/STBD/TOP	25.14	23.38	15.66	19.24	17.47
DIST ABV BASELINE FWD, FT	45.86	55.86	65.86	43.67	53.67
DIST ABV BASELINE AFT, FT	44.31	55.86	65.86	45.04	53.67
HEIGHT, FT	10.00	10.00	10.00	10.00	10.00
VOLUME, FT3	32306.	27943.	6650.	24810.	24364.
ARR AREA, FT2	2939.2	2739.5	651.9	2608.3	2388.7

6. DECKHOUSE STRUCTURE WEIGHT SUMMARY

DKHS MTRL TYPE IND-MS
FIRE PROTECT IND-NONE
BLAST RESIST IND-7 PSI

DKHS STRUCT DENSITY, LBM/FT3 4.18
HANGER VOL, FT3 0.

	WT-LTON	VCG-FT	LCG-FT
CALCULATED SWBS150	223.1	55.48	297.54

DECK HOUSE	VOLUME FT3	VCG FROM BL FT
NO. 1	32306.	50.40
NO. 2	27943.	60.80
NO. 3	6650.	70.77
NO. 4	24810.	48.94
NO. 5	24364.	58.60
	116073.	55.48

7. HULL STRUCTURE MODULE SUMMARY

INNER BOT IND-PRESENT
STIFFENER SHAPE IND-CALC

HULL LOADS IND-CALC

HULL STRENGTH AND STRESS

HOGGING BM, FT-LTON	209534.	PRIM STRESS KEEL-HOG, KSI	16.63
SAGGING BM, FT-LTON	174688.	PRIM STRESS KEEL-SAG, KSI	13.86
MIDSHIP MOI, FT2-IN2	616564.	PRIM STRESS DECK-HOG, KSI	16.22
DIST N.A. TO KEEL, FT	21.84	PRIM STRESS DECK-SAG, KSI	13.52
DIST N.A. TO DECK, FT	21.30	HULL MARGIN STRESS, KSI	2.24
SEC MOD TO KEEL, FT-IN2	28229.	SEC MOD TO DECK, FT-IN2	28940.

HULL STRUCTURE COMPONENTS

	MATERIAL TYPE	NO OF SEGMENT	NO
WET. DECK	OS	2	1
SIDE SHELL	OS	4	1
BOTTOM SHELL	OS	6	1
INNER BOTTOM	OS	7	1
INT. DECK	OS	1	3
STRINGER, SHEER	HY 80	1	1
LONG BULKHEAD			0
TRANS BULKHEAD	OS		14

HULL STRUCTURE WEIGHT

SWBS	COMPONENT	WEIGHT, LTON	VCG, FT
100	HULL STRUCTURE	2453.4	27.08
110	SHELL+SUPPORT	1104.2	20.43
120	HULL STRUCTURAL BHD	209.4	25.88
130	HULL DECKS	741.4	40.49
140	HULL PLATFORM/FLATS	398.3	21.20

8. HULL STRUCTURE MODULE WEIGHT DATA

SWBS	COMPONENT	WT-LTON	VCG-FT
100	HULL STRUCTURES	2453.4	27.08
*110	SHELL + SUPPORTS	1104.2	20.43
111	PLATING	600.7	23.22
113	INNER BOTTOM	88.0	4.29
115	STANCHIONS	19.3	21.56
116	LONG FRAMING	169.3	2.43
117	TRANS FRAMING	216.2	32.30
120	HULL STRUCTURAL BULKHDS	209.4	25.88
121	LONG BULKHDS		
122	TRANS BULKHDS	179.0	25.88
123	TRUNKS + ENCLOSURES	30.4	25.88
130	HULL DECKS	741.4	40.49
131	MAIN DECK	374.5	35.95
132	2ND DECK		
133	3RD DECK		
134	4TH DECK		
135	5TH DECK+DECKS BELOW		
136	01 HULL DECK	366.9	45.13
140	HULL PLATFORMS/FLATS	398.3	21.20
141	1ST PLATFORM	230.9	25.75
142	2ND PLATFORM	167.4	14.93
143	3RD PLATFORM		
144	4TH PLATFORM		
145	5TH PLAT+PLATS BELOW		

9. APPENDAGE MODULE WARNINGS

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

** WARNING - APPENDAGE MODULE ** (W-FINROTATSHIFT-FINREP)
FWD FINS HAVE BEEN RE-POSITIONED BY SHIFTING FIN ROOT
Z-COORD. -1.30 FT (UPWARD POSITIVE) AND BY ROTATING
ABOUT FIN ROOT 9.00 DEG (CLOCKWISE POSITIVE).
** WARNING - APPENDAGE MODULE ** (W-FINROTATSHIFT-FINREP)
AFT FINS HAVE BEEN RE-POSITIONED BY SHIFTING FIN ROOT
Z-COORD. -1.29 FT (UPWARD POSITIVE) AND BY ROTATING
ABOUT FIN ROOT 8.00 DEG (CLOCKWISE POSITIVE).

10. APPENDAGE MODULE DATA SUMMARY

APPENDAGE DISP, LTON	191.7		
SHELL DISP, LTON	45.2		
SKEG IND	NONE	RUDDER TYPE IND	INTEGRAL
SKEG DISP, LTON	0.0	NO RUDDERS	2
SKEG AFT LIMIT/LBP	0.0000	AVG RUDDER CHORD, FT	10.55
SKEG THK, FT	0.00	RUDDER THK, FT	1.73
SKEG PROJECTED AREA, FT2	0.0	RUDDER SPAN, FT	22.95
		RUDDER PROJECTED AREA, FT2	242.1
BILGE KEEL IND	NONE	RUDDER DISP, LTON	11.3
BILGE KEEL DISP, LTON	0.0		
BILGE KEEL LGTH, FT	0.00	FIN SIZE IND	CALC
		NO FIN PAIRS	2
SHAFT SUPPORT TYPE IND	POD	FWD FIN	
SHAFT SUPPORT DISP, LTON	131.7	CHORD, FT	5.76
SHAFT DISP, LTON	0.0	THK, FT	.86
		SPAN, FT	5.76
PROP TYPE IND	CR	PROJECTED AREA, FT2	33.2
PROP BLADE DISP, LTON	1.3	DISP, LTON (PER PAIR)	1.1
NO PROP SHAFTS	2	AFT FIN	
PROP DIA, FT	14.94	CHORD, FT	5.70
		THK, FT	.85
SONAR DOME IND	NONE	SPAN, FT	5.70
SONAR DISP, LTON	0.0	PROJECTED AREA, FT2	32.5
		DISP, LTON (PER PAIR)	1.1

11. APPENDAGE MODULE, APPENDAGE BUOYANCY AND WEIGHT DATA

APPENDAGE	DISP, LTON	----CENTER OF BUOYANCY---- X, FT	Y, FT	Z, FT
SHELL	45.2	292.26	0.00	11.92
PODS*	131.7	559.81	11.20	5.31
PROP BLADES*	1.3	543.25	11.20	3.23
RUDDERS*	11.3	574.14	11.20	11.88
FWD ROLL FIN PAIR*	1.1	259.94	24.74	5.15
AFT ROLL FIN PAIR*	0.5	317.71	25.37	5.09
TOTAL, LTON	191.7			

* TRANSVERSE C.B. PER SIDE IS SHOWN

SWBS114, SHLL APNDG, LTON 0.00 SWBS565, ROLL FINS, LTON 23.45

12. RESISTANCE MODULE SUMMARY

RESID RESIST IND	TAYLOR	BILGE KEEL IND	NONE
FRICTION LINE IND	ITTC	SHAFT SUPPORT TYPE IND	POD
ENDUR DISP IND	FULL LOAD	PRPLN SYS RESIST IND	CALC
ENDUR CONFIG IND	NO TS	PROP TYPE IND	CR
SONAR DRAG IND		SONAR DOME IND	NONE
SKEG IND	NONE	RUDDER TYPE IND	INTEGRAL
FULL LOAD WT, LTON	8416.8	CORR ALW	0.00050
AVG ENDUR DISP, LTON	8416.8	DRAG MARGIN FAC	0.000
USABLE FUEL WT, LTON	1052.7	TRAILSHAFT PWR FAC	1.15
NO FIN PAIRS	2.	PRPLN SYS RESIST FRAC	
PROP TIP CLEAR RATIO	0.25	MAX SPEED	0.223
NO PROP SHAFTS	2.	SUSTN SPEED	0.249
PROP DIA, FT	14.94	ENDUR SPEED	0.358

CONDITION	SPEED	------------	------------	EFFECTIVE HORSEPOWER, HP	------------	------------		DRAG
	KT	FRIC	RESID	APPDG	WIND	MARGIN	TOTAL	LBF
MAX	30.28	15439.	12068.	6493.	566.	0.	34566.	371950.
SUSTN	28.84	13389.	7988.	5633.	489.	0.	27499.	310738.
ENDUR	20.00	4613.	1579.	2321.	163.	0.	8676.	141360.

13. RESISTANCE MODULE SPEED -- POWER MATRIX

RESID RESIST IND	TAYLOR
ENDUR DISP IND	FULL LOAD

SPEED AND POWER FOR FULL LOAD DISP
==================================

FULL LOAD WT, LTON 8416.8

SPEED	------------	------------	EFFECTIVE HORSEPOWER, HP	------------	------------		DRAG
KT	FRIC	RESID	APPDG	WIND	MARGIN	TOTAL	LBF
2.00	6.	1.	12.	0.	0.	19.	3035.
4.00	43.	9.	56.	1.	0.	110.	8925.
6.00	140.	30.	143.	4.	0.	316.	17179.
8.00	322.	70.	276.	10.	0.	678.	27632.
10.00	615.	137.	461.	20.	0.	1233.	40191.
12.00	1044.	237.	701.	35.	0.	2018.	54792.
14.00	1635.	385.	1001.	56.	0.	3077.	71631.
16.00	2410.	587.	1364.	83.	0.	4444.	90512.
18.00	3395.	894.	1795.	119.	0.	6203.	112299.
20.00	4613.	1579.	2321.	163.	0.	8676.	141360.
22.00	6088.	2205.	2901.	217.	0.	11411.	169027.
24.00	7843.	2988.	3558.	282.	0.	14670.	199189.
26.00	9902.	4138.	4307.	358.	0.	18705.	234435.
28.00	12287.	6475.	5204.	447.	0.	24413.	284115.
30.00	15022.	11142.	6315.	550.	0.	33029.	358768.
32.00	18130.	18772.	7663.	668.	0.	45233.	460624.

14. PROPELLER MODULE SUMMARY

ENDUR CONFIG IND	NO TS		
PROP TYPE IND	CR	PROP SERIES IND	ANALYTIC2
PROP DIA IND	GIVEN	PROP LOC IND	GIVEN
PROP AREA IND	GIVEN	PROP ID IND	CR 0.75EAR
SHAFT SUPPORT TYPE IND		RUDDER TYPE IND	
MAX SPEED, KT	30.28	ENDUR SPEED, KT	20.00
MAX EHP (/SHAFT), HP	17283.	ENDUR EHP (/SHAFT), HP	4338.
MAX SHP (/SHAFT), HP	21950.	ENDUR SHP (/SHAFT), HP	5494.
MAX PROP RPM	164.1	ENDUR PROP RPM	105.9
MAX PROP EFF	0.787	ENDUR PROP EFF	0.790
SUSTN SPEED, KT	28.84	PROP DIA, FT	14.94
SUSTN EHP (/SHAFT), HP	13749.	NO BLADES	5.
SUSTN SHP (/SHAFT), HP	17426.	PITCH RATIO	1.28
SUSTN PROP RPM	154.1	EXPAND AREA RATIO	0.750
SUSTN PROP EFF	0.789	CAVITATION NO	1.41
NO PROP SHAFTS	2.0		
TOTAL PROPELLER WT, LTON	16.75		

15. PROPELLER MODULE DETAIL CHARACTERISTICS

PROP ID IND	CR 0.75EAR
NO PROP SHAFTS	2.
PROP DIA, FT	14.94
NO BLADES	5.
PITCH RATIO	1.28
EXPAND AREA RATIO	0.750
THRUST DED COEF	0.076
TAYLOR WAKE FRAC	0.076
HULL EFFICIENCY	1.000
REL ROTATE EFF	1.000

	----------- CONDITIONS	----------	
CHARACTERISTICS	MAXIMUM	SUSTAINED	ENDURANCE
SPEED, KT	30.28	28.84	20.00
RPM	164.1	154.1	105.9
THRUST/SHAFT, LBF	201274.	168150.	76494.
EHP/SHAFT, HP	17283.	13749.	4338.
TORQUE/SHAFT, FT-LBF	702323.	557579.	175797.
SHP/SHAFT, HP	21950.	17426.	5494.
ADVANCE COEF (J)	1.156	1.172	1.183
THRUST COEF (KT)	0.317	0.300	0.289
TORQUE COEF (10KQ)	0.740	0.710	0.690
OPEN WATER EFFY	0.787	0.789	0.790
PC	0.787	0.789	0.790

16. PROPELLER CAVITATION CHARACTERISTICS

MAX SPEED OF ADV, KT	27.98
MAX THRUST, LBF	201274.
MAX PROP RPM	164.1
PROP DIA, FT	14.94
HUB DEPTH, FT	15.84
STD CAV NO	1.41
LOCAL CAV NO (.7R)	0.30
MEAN THRUST LOADING COEF	0.18
EXPAND AREA RATIO	0.750
MIN EAR REQUIRED	0.824
BACK CAV ALLOWED, PERCENT	10.0

THRUST LOADING EXCEEDS BURRILL'S CRITERIA

PRINTED REPORT NO. 4 - PROPELLER ARRANGEMENT

PROP DIA, FT	14.94
FULL LOAD DRAFT, FT	19.07
HUB DEPTH FROM DWL, FT	15.84
LONG LOC FROM AP, FT	34.41
HUB POS FROM CL, FT	11.20
TIP CLR FROM BL, FT	-4.24
TIP CLR FROM MAX HB, FT	14.23
TIP CLR FROM HULL BOT, FT	3.72

TOTAL PROPELLER WT, LTON	16.75

17. MACHINERY MODULE WARNINGS

** WARNING - MACHINERY MODULE ** (W-SEPSSGEN2SMALL-MHYMSG)
GENERATING CAPACITY OF SEPARATE SHIP-SERVICE GENERATORS IS INADEQUATE TO MEET REQUIRED LOAD AT ONE OR MORE CONDITIONS. INCREASE EITHER NUMBER OF INSTALLED GENERATORS (SS ARR NO ARRAY), NUMBER OF OPERATING GENERATORS (SEP SS GEN OP ARRAY), OR INCREASE GENERATOR RATING (SEP SS GEN KW).

SEP SS GEN KW (AVAIL)	3000.0
SEP SS GEN KW REQ	3663.7

18. MACHINERY MODULE SUMMARY

TRANS TYPE IND	ELECT	MAX SPEED, KT	30.28
ELECT PRPLN TYPE IND	ACC-AC	SUSTN SPEED IND	CALC
SHAFT SUPPORT TYPE IND	POD	SUSTN SPEED, KT	28.84
NO PROP SHAFTS	2.	ENDUR SPEED IND	GIVEN
ENDUR CONFIG IND	NO TS	ENDUR SPEED, KT	20.00
SEC ENG USAGE IND		DESIGN MODE IND	ENDURANCE
MAX MARG ELECT LOAD, KW	4706.	ENDURANCE, NM	8000.
AVG 24 HR ELECT LOAD, KW	2343.	USABLE FUEL WT, LTON	1052.7
SWBS 200 GROUP WT, LTON	393.3		
SWBS 300 GROUP WT, LTON	263.4		

ARRANGEMENT OR SS GEN	TYPE	NO INSTALLED	NO ONLINE MAX+SUSTN	NO ONLINE ENDURANCE
ELECT PG ARR 1 IND	M-CG-PG	2	2	2
ELECT PG ARR 2 IND	M-CG-PG	0	0	0
ELECT DL ARR IND	MTR-E-E	2	2	2
SEP SS GEN	3000. KW	1	0	0
VSCF SS CYCLO	3000. KW	2	2	2

	MAIN ENG	SEC ENG	SS ENG
ENG SELECT IND	GIVEN		GIVEN
ENG MODEL IND	GE-LM1600-VAN2		DDA-501-K34
ENG TYPE IND	RGT		GT
ENG SIZE IND	GIVEN		GIVEN
NO INSTALLED	2	0	1
ENG PWR AVAIL, HP	26400.		4600.
ENG RPM	3600.0		14300.0
ENG SFC, LBM/HP-HR	0.328		.473
ENG LOAD FRAC	1.000		.920

19. MACHINERY EQUIPMENT LIST

NO EACH	ITEM	WEIGHT LTON	LENGTH FT	WIDTH FT	HEIGHT FT
	PROPULSION PLANT				
2	MAIN ENGINE (BARE)	3.3	12.00	5.60	5.60
2	MAIN ENGINE ENCLOSURE MODULE	11.5	23.76	9.10	8.40
2	MAIN ENGINE INTERCOOLER	3.8	5.62	6.34	6.34
0	SEC ENGINE (BARE)				
0	SEC ENGINE ENCLOSURE MODULE				
0	SEC ENGINE INTERCOOLER				
0	RACER STEAM TURBINE				
0	RACER CONDENSER				
0	LTDR GEAR (01)				
0	EPIC REV PINION GEAR (02)				
0	FRANCO TOSI REV GEAR (03)				
0	VSCF COMB/STEP-UP GEAR (04)				
0	RACER REDUCTION GEAR (05)				
0	2 SPD SOLAR EPIC GEAR (06)				
0	OFFSET GEAR (07)				
0	OFFSET COMB (2-1) GEAR (08)				
0	OFFSET COMB (3-2) GEAR (09)				
2	CR EPIC GEAR (10)	6.2	3.74	5.85	5.85
0	Z DRIVE SPIRAL BVL GEAR (11)				
0	PLANETARY REDUCTION GEAR(12)				
0	CR BI-COUPLED EPIC GEAR (13)				
0	STAR EPIC REV GEAR (14)				
2	STAR EPIC REDUCTION GEAR(15)	1.3	2.27	3.17	3.17
2	COMBINING STEP-UP GEAR (16)	1.1	1.82	7.18	2.04
2	PROPULSION GENERATOR	11.7	10.50	6.13	6.13
2	PROPULSION MOTOR	9.3	8.63	6.13	6.13
2	THRUST BEARING	7.8	5.16	4.23	4.23
2	PROPELLER SHAFT				
	ELECTRIC PLANT				
1	SS ENGINE (BARE)	.6	7.50	2.80	2.60
1	SS ENGINE ENCLOSURE MODULE	5.6	16.76	6.85	8.56
1	SS REDUCTION GEAR (17)	2.5	4.17	4.05	5.96
1	SEPARATE SS GENERATOR	9.8	9.71	3.60	5.10
2	VSCF SS GENERATOR	3.6	4.96	2.50	2.50
2	VSCF SS CYCLOCONVERTER	4.1			

20. MACHINERY MODULE ENGINES DATA

	MAIN ENG	SEC ENG	SS ENG
ENG SELECT IND	GIVEN		GIVEN
ENG TYPE IND	RGT		GT
ENG MODEL IND	GE-LM1600-VAN2		DDA-501-K34
ENG SIZE IND	GIVEN		GIVEN
NO INSTALLED	2	0	1
ENG BARE WT, LTON	3.3		.6
ENG LENGTH, FT	12.00		7.50
ENG WIDTH, FT	5.60		2.80
ENG HEIGHT, FT	5.60		2.60
ENG PWR AVAIL, HP	26400.		4600.0
ENG RPM	3600.0		14300.0
ENG MASS FL, LBM/SEC	117.1		36.1
ENG EXH TEMP, DEGF	668.0		1025.0
ENG SFC EQN IND	POLY QN		POLY 2
ENG SFC, LBM/HP-HR	0.328		.473
MAX SPEED CONDITION			
NO OPERATING	2	0	0
ENG PWR, HP	26400.		.0
ENG RPM	3600.0		14300.0
ENG MASS FL, LBM/SEC	117.1		.0
ENG EXH TEMP, DEGF	668.0		
ENG SFC, LBM/HP-HR	.328		
SUSTN SPEED CONDITION			
NO OPERATING	2	0	0
ENG PWR, HP	21655.		.0
ENG RPM	3379.6		14300.0
ENG MASS FL, LBM/SEC	108.5		.0
ENG EXH TEMP, DEGF	617.3		
ENG SFC, LBM/HP-HR	.318		
ENDUR SPEED CONDITION			
ENG ENDUR RPM IND	CALC		
NO OPERATING	2	0	0
ENG PWR, HP	8498.		.0
ENG RPM	3600.0		14300.0
ENG MASS FL, LBM/SEC	75.7		.0
ENG EXH TEMP, DEGF	505.5		
ENG SFC, LBM/HP-HR	.318		

NOTE - ENGINE OPERATING DATA ARE BASED ON USE OF DFM FUEL.

21. MACHINERY MODULE GEAR DATA

NO EACH	ITEM	WEIGHT LTON	LENGTH FT	WIDTH FT	HEIGHT FT
	2-STAGE REDUCTION GEARS				
0	LTDR GEAR (01)				
0	CR BI-COUPLED EPIC GEAR (13)				
	1ST STAGE REDUCTION GEARS				
0	OFFSET GEAR (07)				
0	OFFSET COMB (2-1) GEAR (08)				
0	OFFSET COMB (3-2) GEAR (09)				
2	STAR EPIC REDUCTION GEAR(15)	1.3	2.27	3.17	3.17
	2ND STAGE REDUCTION GEARS				
2	CR EPIC GEAR (10)	6.2	3.74	5.85	5.85
0	PLANETARY REDUCTION GEAR(12)				
	SPECIAL GEARS				
0	EPIC REV PINION GEAR (02)				
0	FRANCO TOSI REV GEAR (03)				
0	VSCF COMB/STEP-UP GEAR (04)				
0	RACER REDUCTION GEAR (05)				
0	2 SPD SOLAR EPIC GEAR (06)				
0	Z DRIVE SPIRAL BVL GEAR (11)				
0	STAR EPIC REV GEAR (14)				
2	COMBINING STEP-UP GEAR (16)	1.1	1.82	7.18	2.04
1	SS REDUCTION GEAR (17)	2.5	4.17	4.05	5.96

REDUCTION GEAR DESIGN FACTORS AND DIMENSIONS	1ST STAGE	2ND STAGE	SS
REDUCTION RATIO	2.67	8.20	7.94
K FACTOR	350.0	350.0	175.0
FACE WIDTH RATIO	1.000	1.000	2.300
CASING WT FACTOR	.520	.520	3.000
GEAR FACE WIDTH, FT	.86	1.18	.90
PINION GEAR DIA, FT			.39
REDUCTION GEAR DIA, FT			3.11
SUN GEAR DIA, FT	.86	1.18	
PLANET GEAR DIA, FT	.72	1.53	
RING GEAR DIA, FT	2.30	4.24	
RING GEAR THK, FT	.16	.30	
NO PLANETS	6	5	

22. MACHINERY MODULE - ELECTRIC PROPULSION AND VSCF EQUIPMENT

TRANS TYPE IND-ELECT
ELECT PRPLN TYPE IND-ACC-AC
SWITCHGEAR TYPE IND-ADV
TRANS LINE NODE PT IND-CALC
ELECT PRPLN RATING IND-CALC

TRANS LINE NODE PT X, FT	451.77
TRANS LINE NODE PT Y, FT	14.54
TRANS LINE NODE PT Z, FT	21.56

MOTORS AND GENERATORS

	PRPLN GENERATOR	PRPLN MOTOR	VSCF GENERATOR
INSTALLED NUMBER	2	2	2
TYPE	AC	AC	AC
FREQUENCY CONTROL	YES		
DRIVE		GEARED	GEARED
ROTOR COOLING	LIQUID	LIQUID	LIQUID
ROTOR TIP SPEED, FT/MIN	28500.	28500.	24500.
STATOR COOLING	LIQUID	LIQUID	LIQUID
ARM ELECT LOAD, AMP/IN	2400.	2400.	2000.
POWER RATING, MW	24.80	18.64	3.00
ROTATIONAL SPEED, RPM	3600.	3600.	6000.
NUMBER OF POLES	4.	4.	12.
LENGTH, FT	10.5	8.6	5.0
WIDTH, FT	6.1	6.1	2.5
HEIGHT, FT	6.1	6.1	2.5
WEIGHT, LTON	11.7	9.3	3.6

OTHER ELECTRIC PROPULSION AND VSCF EQUIPMENT

	WEIGHT LTON
CONTROLS	1.4
BRAKING RESISTORS	7.5
EXCITERS	14.1
SWITCHGEAR	2.1
POWER CONVERTERS	16.4
DEIONIZED COOL WATER SYS	13.4
PRPLN TRANS LINE	22.8
RECTIFIERS	.0
HELIUM REFRIGERATION SYS	.0
VSCF CYCLOCONVERTERS	8.2

23. MACHINERY MODULE - SHIP SERVICE GENERATORS

SS SYS TYPE IND-PD
GEN SIZE IND-GIVEN

ELECT LOAD DES MARGIN FAC	0.050
ELECT LOAD SL MARGIN FAC	0.050
ELECT LOAD IMBAL FAC	0.900
MAX MARG ELECT LOAD, KW	4706.1
MAX STANDBY LOAD, KW	3297.3
24 HR AVG ELECT LOAD, KW	2343.2

VSCF SS CYCLOCONVERTERS

CONDITION	NO INSTALL	NO ONLINE	REQ KW/CYCLO	AVAIL KW/CYCLO	LOADING FRAC
WINTER BATTLE	2	2	1871.	3000.	0.624
WINTER CRUISE	2	2	2353.	3000.	0.784
SUMMER CRUISE	2	2	1683.	3000.	0.561
ENDURANCE(24 HR AVG)	2	2	1172.	3000.	0.391

SEPARATE SS GENERATORS

CONDITION	NO INSTALL	NO ONLINE	REQ KW/GEN	AVAIL KW/GEN	LOADING FRAC
WINTER BATTLE	1	0	.	3000.	0.000
WINTER CRUISE	1	0	.	3000.	0.000
SUMMER CRUISE	1	0	.	3000.	0.000
ENDURANCE(24 HR AVG)	1	0	.	3000.	0.000

TOTALS

CONDITION	REQ KW	AVAIL KW	LOADING FRAC
WINTER BATTLE	3742.	6000.	0.624
WINTER CRUISE	4706.	6000.	0.784
SUMMER CRUISE	3366.	6000.	0.561
ENDURANCE(24 HR AVG)	2343.	6000.	0.391

24. MACHINERY MODULE - INTAKE DUCTS

INLET TYPE IND-PLENUM
DUCT SILENCING IND-BOTH
GT ENG ENCL IND-84 DBA

	MAIN ENG	SEC ENG	SS ENG
ENG TYPE	RGT		GT
INLET DUCT XSECT AREA,FT2	86.1	.0	25.7
INLET DUCT XSECT LTH, FT	9.46	.0	7.2
INLET DUCT XSECT WID, FT	9.10	.0	3.6

MMR1

	----MAIN ENG-----		-----SEC ENG-----	
	WT,LTON	VCG,FT	WT,LTON	VCG,FT
INLET	0.7	61.86		
INLET DUCTING	1.7	45.81		
INLET SILENCER	2.3	47.53		
GT COOLING SUPPLY	1.8	37.95		
GT BLEED AIR SUPPLY	3.4	33.08		

MMR2

	----MAIN ENG-----		-----SEC ENG-----	
	WT,LTON	VCG,FT	WT,LTON	VCG,FT
INLET	0.7	59.67		
INLET DUCTING	1.6	44.72		
INLET SILENCER	2.3	47.53		
GT COOLING SUPPLY	1.7	37.14		
GT BLEED AIR SUPPLY	3.4	32.51		

NOTE - NUMERIC DATA PRESENTED ABOVE ARE ON A PER ENGINE BASIS.

TRUNK AREA AND VOLUME REQUIREMENTS

	-----AREA,FT2----		---VOLUME,FT3----	
ENGINE CATEGORY	HULL	DKHS	HULL	DKHS
MAIN ENGINES	209.2	418.5	1890.	4276.
SECONDARY ENGINES	0.0	0.0	0.	0.
SHIP-SERVICE ENGINES	71.7	107.5	685.	1083.
TOTALS	280.9	526.0	2575.	5359.

25. MACHINERY MODULE - EXHAUST DUCTS

EXHAUST IR SUPPRESS IND-PRESENT
DUCT SILENCING IND-BOTH
GT ENG ENCL IND-84 DBA

EXHAUST STACK TEMP, DEGF	350.0
EDUCTOR DESIGN FAC	1.000

	MAIN ENG	SEC ENG	SS ENG
ENG TYPE	RGT		GT
ENG EXH TEMP, DEG	668.		1006.
ENG MASS FL, LBM/SEC	117.1		35.0
EXH DUCT GAS TEMP, DEG	601.		898.
EXH DUCT GAS DEN, LBM/FT3	0.0368		.0288
EXH DUCT MASS FL, LBM/SEC	133.5		39.9
EXH DUCT AREA, FT2	33.7		12.9

MMR1

	MAIN ENG WT,LTON	MAIN ENG VCG,FT	SEC ENG WT,LTON	SEC ENG VCG,FT
EXH DUCT (TO BOILER/REG)				
EXH BOILER (RACER)				
EXH REGENERATOR	18.1	30.52		
EXH DUCT (TO STACK)	4.9	50.57		
EXH SILENCER	6.0	51.06		
EXH STACK	1.7	72.16		
EXH SPRAY RING	.6	51.24		
EXH EDUCTOR	3.2	71.88		

MMR2

	MAIN ENG WT,LTON	MAIN ENG VCG,FT	SEC ENG WT,LTON	SEC ENG VCG,FT
EXH DUCT (TO BOILER/REG)				
EXH BOILER (RACER)				
EXH REGENERATOR	18.1	30.52		
EXH DUCT (TO STACK)	4.6	49.47		
EXH SILENCER	6.0	51.06		
EXH STACK	1.7	69.97		
EXH SPRAY RING	.6	49.78		
EXH EDUCTOR	3.2	69.69		

NOTE - NUMERIC DATA PRESENTED ABOVE ARE ON A PER ENGINE BASIS.

TRUNK AREA AND VOLUME REQUIREMENTS

ENGINE CATEGORY	AREA,FT2 HULL	AREA,FT2 DKHS	VOLUME,FT3 HULL	VOLUME,FT3 DKHS
MAIN ENGINES	353.9	483.1	3196.	4937.
SECONDARY ENGINES	0.0	0.0	0.	0.
SHIP-SERVICE ENGINES	133.4	200.1	1275.	2015.
TOTALS	487.3	683.2	4471.	6952.

26. MACHINERY MODULE DATA FOR PROPELLERS AND SHAFTS

SHAFT SUPPORT TYPE IND-POD
SHAFT SYS SIZE IND-CALC
PROP TYPE IND-CR

FWD PROP DIA, FT	14.94
AFT PROP DIA, FT	14.34
HUB DIA, FT	6.28
FWD PROP BLADE WT, LTON	2.6
AFT PROP BLADE WT, LTON	2.3
FWD PROP HUB WT, LTON	2.1
AFT PROP HUB WT, LTON	1.4
INR BEND STRESS CON FAC	1.000
OTR BEND STRESS CON FAC	1.700
INR OVRHG PROP MOM ARM RATIO	0.530
OTR OVRHG PROP MOM ARM RATIO	0.280
CR SHAFT TORQUE RATIO	1.000
CR SHAFT CLEAR RATIO	1.380
EQUIV FP PROP WT, LTON	13.7
ALLOW BEND STRESS, LBF/IN2	6000.
FATIGUE LIMIT, LBF/IN2	47500.
YIELD POINT, LBF/IN2	75000.
TORQUE MARGIN FAC	1.200
OFF-CENTER THRUST FAC	1.000
NO STRUTS PER SHAFT	0

PORT SHAFT

	PROP SECTION	INTERMED SECTION	LINE SECTION
ANGLE, DEG	-3.25		
LENGTH, FT	3.73		
DIAMETER, FT	1.24		
BORE RATIO	.200		
WEIGHT, LTON	1.3		
LCG, FT	547.72		
TCG, FT	-11.20		
VCG, FT	3.48		
FACTOR OF SAFETY			

STBD SHAFT

	PROP SECTION	INTERMED SECTION	LINE SECTION
ANGLE, DEG	-3.25		
LENGTH, FT	3.73		
DIAMETER, FT	1.24		
BORE RATIO	.200		
WEIGHT, LTON	1.3		
LCG, FT	547.72		
TCG, FT	11.20		
VCG, FT	3.48		
FACTOR OF SAFETY			

27. MACHINERY MODULE DATA FOR STRUTS, PODS, AND RUDDERS

SHAFT SUPPORT TYPE IND-POD
SHAFT SYS SIZE IND-CALC

PROP DIA, FT	14.94
NO STRUTS PER SHAFT	0
NO SHAFTS	2
OVRHG PROP MOM ARM RATIO	0.530

STRUTS

	MAIN STRUT	INTERMED STRUT
WALL THICKNESS, FT		
CHORD, FT		
THICKNESS, FT		
BARREL LTH, FT		
BARREL DIA, FT		

PODS

STRUT WALL THICKNESS, FT	.06
STRUT CHORD, FT	14.82
STRUT THICKNESS, FT	3.21
BARREL LTH, FT	42.34
BARREL DIA, FT	9.64

RUDDERS

RUDDER TYPE IND-INTEGRAL
RUDDER SIZE IND-CALC

RUDDER WT (PER), LTON	34.9
RUDDER DISP (PER), LTON	5.7

	CHORD,FT	THICK,FT	SPAN,FT
INTEGRAL RUDDER (UPR)	11.11	1.11	17.63
INTEGRAL RUDDER (LWR)	17.34	1.73	2.65

28. MACHINERY MODULE - ELECTRIC LOADS

400 HZ ELECT LOAD FAC 0.000

PAYLOAD LOADS	WINTER CRUISE KW	WINTER BATTLE KW	SUMMER CRUISE KW
COMMAND AND SURVEILLANCE (60 HZ)	130.4	152.8	130.4
COMMAND AND SURVEILLANCE (400 HZ)	0.0	0.0	0.0
ARMAMENT (60 HZ)	510.6	563.8	510.6
ARMAMENT (400 HZ)	0.0	0.0	0.0
OTHER PAYLOAD (60 HZ)	0.0	0.0	0.0
OTHER PAYLOAD (400 HZ)	0.0	0.0	0.0
SUB-TOTAL	641.0	716.6	641.0
NON-PAYLOAD LOADS (* INDICATES USER ADJUSTED VALUE)			
PROPULSION AND STEERING	285.7	331.5	185.7
LIGHTING	236.0	231.3	236.0
MISCELLANEOUS ELECTRIC	46.1	40.1	46.1
HEATING	1444.7	736.8	72.2
VENTILATION	646.6	497.9	646.6
AIR CONDITIONING	512.9	482.1	765.5
AUXILIARY BOILER AND FRESH WATER	188.9	139.8	188.9
FIREMAIN	115.0	162.1	115.0
UNREP AND HANDLING	20.7	5.0	20.7
MISC AUXILIARY MACHINERY	66.9	37.5	66.9
SERVICES AND WORK SPACES	77.7*	29.0*	77.7*
SUBTOTAL	3641.2	2693.0	2421.4
TOTAL	4282.2	3409.6	3062.4
TOTAL (INCLUDING MARGINS)	4706.1	3741.7	3366.5

MAX MARG ELECT LOAD	4706.1
24 HR AVG ELECT LOAD	2343.2
CONNECTED ELECT LOAD	11347.8
ANCHOR ELECT LOAD	3297.3
VITAL ELECT LOAD	1648.2
EMERGENCY ELECT LOAD	1667.9
MAX STBY ELECT LOAD	3297.3

29. MACHINERY MODULE POWERING DATA

SUSTN SPEED IND-CALC
ENDUR SPEED IND-GIVEN
TRANS EFF IND-CALC

100 PCT POWER TRANS EFF	0.9244
25 PCT POWER TRANS EFF	0.8829

	MAX SPEED	SUSTN SPEED	ENDUR SPEED
SHIP SPEED, KT	30.28	28.84	20.00
PROP RPM	164.1	154.1	105.9
NO OF PROP SHAFTS	2	2	2
EHP (/SHAFT), HP	17283.	13749.	4338.
PROPULSIVE COEF	0.787	0.789	0.790
ENDUR PWR ALW	1.0	1.0	1.1
SHP (/SHAFT), HP	21950.	17426.	6044.
TRANS EFFY	0.924	0.917	0.886
CP PROP TRANS EFFY MULT	1.000	1.000	1.000
PROPUL PWR (/SHAFT), HP	23744.	18995.	6823.
PD GEN PWR (/SHAFT), HP	2656.	2660.	1675.
BHP (/SHAFT), HP	26400.	21655.	8498.

30. MACHINERY MODULE -HULL STRUCTURE AND MISCELLANEOUS WEIGHT

SWBS	COMPONENT	WT,LTON	LCG,FT	VCG,FT
160	SPECIAL STRUCTURES			
161	CASTINGS, FORGINGS, AND WELDMENTS	74.1	430.80	11.21
162	STACKS AND MASTS	3.3	325.55	71.07
180	FOUNDATIONS			
182	PROPULSION PLANT FOUNDATIONS	134.1	407.06	11.30
183	ELECTRIC PLANT FOUNDATIONS	25.4	239.09	23.03

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

31. MACHINERY MOUDLE -- PROPULSION PLANT WEIGHT

SWBS	COMPONENT	WT,LTON	LCG,FT	VCG,FT
200	PROPULSION PLANT	393.3	397.52	19.54
210	ENERGY GENERATING SYSTEM (NUCLEAR)	0.0	0.00	0.00
220	ENERGY GENERATING SYSTEM (NON-NUCLEAR)	0.0	0.00	0.00
230	PROPULSION UNITS	214.5	401.51	17.79
233	PROPULSION INTERNAL COMBUSTION ENGINES	0.0	0.00	0.00
234	PROPULSION GAS TURBINES	96.1	325.55	24.35
235	ELECTRIC PROPULSION	118.3	463.20	12.46
240	TRANSMISSION AND PROPULSOR SYSTEMS	54.5	540.73	4.38
241	PROPULSION REDUCTION GEARS	17.4	526.21	6.33
242	PROPULSION CLUTCHES AND COUPLINGS	0.0	0.00	0.00
243	PROPULSION SHAFTING	3.7	547.72	3.48
244	PROPULSION SHAFT BEARINGS	16.7	551.77	3.71
245	PROPULSORS	16.7	543.25	3.23
250	PRPLN SUPPORT SYS (EXCEPT FUEL+LUBE OIL)	72.2	329.99	40.70
251	COMBUSTION AIR SYSTEM	19.5	324.32	41.30
252	PROPULSION CONTROL SYSTEM	13.5	325.55	28.03
256	CIRCULATING AND COOLING SEA WATER SYSTEM	10.1	363.92	15.52
259	UPTAKES (INNER CASING)	29.0	324.02	54.99
260	PRPLN SUPPORT SYS (FUEL+LUBE OIL)	31.2	316.06	14.71
261	FUEL SERVICE SYSTEM	9.4	296.67	18.35
262	MAIN PROPULSION LUBE OIL SYSTEM	15.6	325.55	12.00
264	LUBE OIL FILL, TRANSFER, AND PURIF	6.2	321.55	16.00
290	SPECIAL PURPOSE SYSTEMS	20.9	337.81	11.11
298	OPERATING FLUIDS	15.6	346.59	8.00
299	REPAIR PARTS AND SPECIAL TOOLS	5.3	311.93	20.27

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

32. MACHINERY MODULE -- ELECTRIC PLANT WEIGHT

SWBS	COMPONENT	WT,LTON	LCG,FT	VCG,FT
300	ELECTRIC PLANT	263.4	285.03	28.10
310	ELECTRIC POWER GENERATION	44.8	214.37	18.07
311	SHIP SERVICE POWER GENERATION	44.8	214.37	18.07
313	BATTERIES AND SERVICE FACILITIES	0.0	0.00	0.00
314	POWER CONVERSION EQUIPMENT	0.0	0.00	0.00
320	POWER DISTRIBUTION SYSTEMS	165.8	309.08	28.02
321	SHIP SERVICE POWER CABLE	123.8	306.16	27.00
324	SWITCHGEAR AND PANELS	42.0	317.71	31.01
330	LIGHTING SYSTEM	36.2	303.59	39.20
331	LIGHTING DISTRIBUTION	20.1	306.16	38.81
332	LIGHTING FIXTURES	16.1	300.38	39.67
340	POWER GENERATION SUPPORT SYSTEMS	13.4	149.85	34.44
342	DIESEL SUPPORT SYSTEMS	0.0	0.00	0.00
343	TURBINE SUPPORT SYSTEMS	13.4	149.85	34.44
390	SPECIAL PURPOSE SYSTEMS	3.1	387.21	20.16
398	OPERATING FLUIDS	0.9	214.37	18.07
399	REPAIR PARTS AND SPECIAL TOOLS	2.2	456.35	21.00

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

33. MACHINERY MODULE -- MAIN & AUX MACHINERY ROOMS

NO MAIN MACHINERY ROOMS	2
NO AUX MACHINERY ROOMS	2
NO OTHER MACHINERY ROOMS	0

BULKHEAD LOCATIONS

MR NO	MR ID	FWD BHD BHD NO	FWD BHD X, FT	FWD BHD X/LBP	AFT BHD BHD NO	AFT BHD X, FT	AFT BHD X/LBP
1	AMR1	4.	151.92	0.263	5.	169.25	0.293
2	MMR1	6.	189.47	0.328	7.	209.69	0.363
3	MMR2	11.	441.90	0.765	12.	462.12	0.800
4	AMR2	12.	462.12	0.800	13.	491.00	0.850

DIMENSIONS

MR NO	MR ID	LENGTH, FT AVAIL	LENGTH, FT REQ	WIDTH, FT AVAIL	WIDTH, FT REQ	HEIGHT, FT AVAIL	HEIGHT, FT REQ
1	AMR1	17.33	13.85	51.74	46.56	26.73	21.03
2	MMR1	20.22	17.91	60.78	40.57	35.75	26.76
3	MMR2	20.22	17.91	60.31	40.57	34.89	26.76
4	AMR2	28.88	0.00	52.93	0.00	25.21	0.00

ARRANGEMENTS

MR NO	MR ID	ROTATION ANGLE,DEG
1	AMR1	90.00
2	MMR1	90.00
3	MMR2	90.00
4	AMR2	0.00

34. MACHINERY MODULE -- MACHINERY ARRANGEMENTS

CLEARANCES (MACHINERY TO MACHINERY)

ENG TO ENG CLR, FT	.80
ENG TO GEAR CLR, FT	1.75
OR ENG TO GEN CLR	
OR GEAR TO GEN CLR	
MTR TO GEAR CLR, FT	1.00
PRPLN ARR TO SS ARR CLR, FT	6.00
AISLE WIDTH CLR, FT	2.80
PORT/CL TB TO GEAR CLR, FT	.00
STBD TB TO GEAR CLR, FT	.00

SEPARATIONS (BETWEEN HULL AND MACHINERY)

LONG (TO BHD), FT	3.50
TRANS (TO SIDE SHELL), FT	1.00
VERT (TO HULL BOT), FT	1.00
RADIAL (TO POD), FT	1.00

ARRANGEMENTS

ARRANGEMENT	TYPE	NO INSTALLED	NO ONLINE MAX+SUSTN	NO ONLINE ENDURANCE
ELECT PG ARR 1 IND	M-CG-PG	2	2	2
ELECT PG ARR 2 IND	M-CG-PG	0	0	0
ELECT DL ARR IND	MTR-E-E	2	2	2
SHIP SERVICE ARR	GT	1	0	0

MACHINERY COMPONENT LOCATIONS

COMPONENT	MR ID	CG LOC, FT X	Y	Z
MAIN ENG	MMR1	199.33	-7.91	21.56
MAIN ENG	MMR2	451.77	-7.91	21.56
SS ENG	AMR1	158.85	-5.47	17.25
PRPLN MTR		566.04	-11.20	4.52
PRPLN MTR		566.04	11.20	4.52

SHAFTING

SHAFT TYPE	END POINT LOC, FT X	Y	Z	SHAFT ANGLE, DEG
PORT SHAFT	549.58	-11.20	3.59	-3.25
STBD SHAFT	549.58	11.20	3.59	-3.25

35. MACHINERY MODULE -- MACHINERY SPACE REQUIREMENTS

MACHINERY ROOM VOLUME REQUIREMENTS

VOLUME CATEGORY	VOLUME, FT3
SWBS GROUP 200	107984.
PROPULSION POWER GENERATION	38870.
PROPULSION ENGINES	26128.
PROPULSION REDUCTION GEARS AND GENERATORS	12742.
DRIVELINE MACHINERY	0.
REDUCTION AND BEVEL GEARS WITH Z-DRIVE	0.
ELECTRIC PROPULSION MOTORS AND GEARS	0.
REMOTELY-LOCATED THRUST BEARINGS	0.
PROPELLER SHAFT	0.
ELECTRIC PROPULSION MISCELLANEOUS EQUIPMENT	13760.
CONTROLS	1760.
BRAKING RESISTORS	1380.
MOTOR AND GENERATOR EXCITERS	2735.
SWITCHGEAR	1676.
POWER CONVERTERS	3574.
DEIONIZED COOLING WATER SYSTEMS	2635.
RECTIFIERS	0.
HELIUM REFRIGERATION SYSTEMS	0.
PROPULSION AUXILIARIES	55353.
PROPULSION LOCAL CONTROL CONSOLES	3934.
CP PROP HYDRAULIC OIL POWER MODULES	0.
FUEL OIL PUMPS	26767.
LUBE OIL PUMPS	3637.
LUBE OIL PURIFIERS	16878.
ENGINE LUBE OIL CONDITIONERS	662.
SEAWATER COOLING PUMPS	3475.
SWBS GROUP 300	43361.
ELECTRIC PLANT POWER GENERATION	13747.
ELECTRIC PLANT ENGINES	9106.
ELECTRIC PLANT GENERATORS AND GEARS	4641.
SHIP SERVICE SWITCHBOARDS	28082.
CYCLOCONVERTERS	1531.
SWBS GROUP 500	61577.
AUXILIARY MACHINERY	61577.
AIR CONDITIONING PLANTS	11576.
AUXILIARY BOILERS	5770.
FIRE PUMPS	6036.
DISTILLING PLANTS	13489.
AIR COMPRESSORS	11324.
ROLL FIN PAIRS	11307.
SEWAGE PLANTS	2076.

ARRANGEABLE AREA REQUIREMENTS

		FT2	
SSCS	GROUP NAME	HULL/DKHS	DKHS ONLY
3.4X	AUXILIARY MACHINERY DELTA	10884.6	0.0
3.511	SHIP SERVICE POWER GENERATION	0.0	0.0
4.132	INTERNAL COMB ENG COMB AIR	0.0	0.0
4.133	INTERNAL COMB ENG EXHAUST	0.0	0.0
4.142	GAS TURBINE ENG COMB AIR	280.9	526.0
4.143	GAS TURBINE ENG EXHAUST	487.3	683.2

NOTE: * DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

36. MACHINERY MODULE -- SURFACE SHIP ENDURANCE CALCULATION FORM

DESIGN MODE IND-ENDURANCE
ENDUR DISP IND-FULL LOAD
ENDUR DEF IND-USN
SHIP FUEL TYPE IND-DFM
ENG ENDUR RPM IND-CALC
SHIP FUEL LHV, BTU/LBM 18360.
DFM FUEL LHV, BTU/LBM 18360.

(1)	ENDURANCE REQUIRED, NM	8000.
(2)	ENDURANCE SPEED, KT	20.00
(3)	FULL LOAD DISPLACEMENT, LTON	8416.8
(3A)	AVERAGE ENDURANCE DISPLACEMENT, LTON	8416.8
(4)	RATED FULL POWER SHP, HP	43899.
(5)	DESIGN ENDURANCE POWER SHP @ (2)&(3A), HP	10988.
(6)	AVERAGE ENDURANCE POWER (SHP), HP (5) X 1.10	12087.
(7)	RATIO, AVG END SHP/RATED F.P. SHP (6)/(4)	0.27534
(8)	AVERAGE ENDURANCE BHP, HP (8A)+(8B)	16996.
(8A)	AVERAGE PRPLN ENDURANCE BHP, HP (6)/TRANSMISSION EFFICIENCY	13646.
(8B)	SHIP SERV PWR SUPPLIED BY PRPLN ENG, HP	3350.
(9)	24 HOUR AVERAGE ELECTRIC LOAD, KW	2343.
(9A)	24 HOUR AVERAGE ELECTRIC LOAD PORTION SUPPLIED BY SS ENG, KW	0.
(10)	CALCULATED PROPULSION FUEL RATE @(8), LBM/HP-HR	0.318
(11)	CALC PRPLN FUEL CONSUMPTION, LBM/HR (10)X(8)	5398.4
(12)	CALC SS GEN FUEL RATE @ (9A), LBM/KW-HR	0.000
(13)	CALC SS GEN FUEL CONSUMPTION, LBM/HR (12)X(9A)	0.0
(14)	CALC FUEL CONSUMPTION FOR OTHER SERVICES, LBM/HR	0.0
(15)	TOTAL CALC ALL-PURPOSE FUEL CONSUMPTION, LBM/HR (11)+(13)+14)	5398.4
(16)	CALC ALL-PURPOSE FUEL RATE, LBM/HP-HR (15)/(6)	0.447
(17)	FUEL RATE CORRECTION FACTOR BASED ON (7)	1.0400
(18)	SPECIFIED FUEL RATE, LBM/HP-HR (16)X(17)	0.464
(19)	AVG ENDURANCE FUEL RATE, LBM/HP-HR (18)X1.05	0.488
(20)	ENDURANCE FUEL (BURNABLE), LTON (1)X(6)X(19)/(2)X2240	1052.7
(21)	TAILPIPE ALLOWANCE FACTOR	0.95
(22)	ENDURANCE FUEL LOAD, LTON (20)/(21)	1108.1

37. MACHINERY MODULE -- MACHINERY MARGINS

PROPULSION PLANT

MAIN ENG MAX LOAD FRAC	1.000
SEC ENG MAX LOAD FRAC	
TORQUE MARGIN FAC	1.200

ELECTRIC PLANT

SS ENG MAX LOAD FRAC	0.920
ELECT LOAD DES MARGIN FAC	0.050
ELECT LOAD SL MARGIN FAC	0.050
ELECT LOAD IMBAL FAC	0.900

38. WEIGHT MODULE SUMMARY

SWBS	GROUP	WEIGHT LTON	WEIGHT PER CENT	LCG FT	VCG FT	RESULTANT ADJ WT-LTON	RESULTANT ADJ VCG-FT
100	HULL STRUCTURE	3402.0	40.4	280.33	27.85	137.3	.56
200	PROP PLANT	393.3	4.7	397.52	19.54		
300	ELECT PLANT	263.4	3.1	285.03	28.10		
400	COMM + SURVEIL	179.1	2.1	219.51	40.51	75.5	.46
500	AUX SYSTEMS	887.0	10.5	317.71	26.57	29.2	.12
600	OUTFIT + FURN	510.2	6.1	288.83	28.81		
700	ARMAMENT	912.0	10.8	259.94	32.77	909.7	3.54
M11	D+B WT MARGIN		0.0	288.78	-----		
	D+B KG MARGIN						
	LIGHTSHIP	6546.9	77.8	288.78	28.29	1151.6	4.67
F00	FULL LOADS	1869.9	22.2	304.44	20.34	675.4	2.68
F10	CREW + EFFECTS	20.6		271.50	32.34		
F20	MISS REL EXPEN	611.0		254.17	35.56		
F30	SHIPS STORES	28.7		311.93	24.26		
F40	FUELS + LUBRIC	1179.7		332.07	12.52		
F50	FRESH WATER	29.9			6.10		
F60	CARGO						
M24	FUTURE GROWTH						
	FULL LOAD WT	8416.8	100.0	292.26	26.53	1827.0	7.35

39. WEIGHT MODULE -- HULL STRUCTURES WEIGHT

SWBS	COMPONENT	WT-LTON	VCG-FT
====	=========	============	===========
100	HULL STRUCTURES	3402.0	27.85
* 110	SHELL + SUPPORTS	1104.2	20.43
111	PLATING	600.7	23.22
113	INNER BOTTOM	88.0	4.29
114	SHELL APPENDAGES		
115	STANCHIONS	19.3	21.56
116	LONGIT FRAMING	169.3	2.43
117	TRANSV FRAMING	216.2	32.30
120	HULL STRUCTURAL BULKHDS	293.3	24.55
121	LONGIT STRUCTURAL BULKHDS	83.9	21.22
122	TRANSV STRUCTURAL BULKHDS	179.0	25.88
123	TRUNKS + ENCLOSURES	30.4	25.88
124	BULKHEADS, TORPEDO PROTECT SYS		
130	HULL DECKS	741.4	40.49
131	MAIN DECK	374.5	35.95
132	2ND DECK		
133	3RD DECK		
134	4TH DECK		
135	5TH DECK+DECKS BELOW		
136	01 HULL DECK	366.9	45.13
137	02 HULL DECK		
138	03 HULL DECK		
139	04 HULL DECK		
140	HULL PLATFORMS/FLATS	398.3	21.20
141	1ST PLATFORM	230.9	25.75
142	2ND PLATFORM	167.4	14.93
143	3RD PLATFORM		
144	4TH PLATFORM		
145	5TH PLAT+PLATS BELOW		
149	FLATS		
150	DECK HOUSE STRUCTURE	223.1	55.48
160	SPECIAL STRUCTURES	261.7	27.51
161	CASTINGS+FORGINGS+EQUIV WELDMT	74.1	11.21
162	STACKS AND MACKS	3.3	71.07
163	SEA CHESTS	4.5	3.70
* 164	BALLISTIC PLATING	126.6	33.91
165	SONAR DOMES		
166	SPONSONS		
167	HULL STRUCTURAL CLOSURES	41.7	30.93
168	DKHS STRUCTURAL CLOSURES	1.8	46.22
169	SPECIAL PURPOSE CLOSURES+STRUCT	9.6	46.53
170	MASTS+KINGPOSTS+SERV PLATFORM	5.5	51.69
171	MASTS,TOWERS,TETRAPODS	5.5	51.69
172	KINGPOSTS AND SUPPORT FRAMES		
179	SERVICE PLATFORMS		
180	FOUNDATIONS	340.8	19.17
181	HULL STRUCTURE FOUNDATIONS		
182	PROPULSION PLANT FOUNDATIONS	134.1	11.30
183	ELECTRIC PLANT FOUNDATIONS	25.4	23.03
184	COMMAND+SURVEILLANCE FDNS	14.7	37.68
185	AUXILIARY SYSTEMS FOUNDATIONS	88.7	19.83
186	OUTFIT+FURNISHINGS FOUNDATIONS	9.5	31.83
187	ARMAMENT FOUNDATIONS	68.4	26.58
190	SPECIAL PURPOSE SYSTEMS	33.7	4.00
191	BALLAST+BOUYANCY UNITS		
197	WELDING AND RIVETS		
198	FREE FLOODING LIQUIDS	33.7	4.00

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

40. WEIGHT MODULE -- PROPULSION PLANT WEIGHT

SWBS	COMPONENT	WT-LTON	VCG-FT
200	PROPULSION PLANT	393.3	19.54
210	ENERGY GEN SYS (NUCLEAR)		
220	ENERGY GENERATING SYSTEM (NONNUC)		
221	PROPULSION BOILERS		
222	GAS GENERATORS		
223	MAIN PROPULSION BATTERIES		
224	MAIN PROPULSION FUEL CELLS		
230	PROPULSION UNITS	214.5	17.79
231	STEAM TURBINES		
232	STEAM ENGINES		
233	DIESEL ENGINES		
234	GAS TURBINES	96.1	24.35
235	ELECTRIC PROPULSION	118.3	12.46
236	SELF-CONTAINED PROPULSION SYS		
237	AUXILIARY PROPULSION DEVICES		
240	TRANSMISSION+PROPULSOR SYSTEMS	54.5	4.38
241	REDUCTION GEARS	17.4	6.33
242	CLUTCHES + COUPLINGS		
243	SHAFTING	3.7	3.48
244	SHAFT BEARINGS	16.7	3.71
245	PROPULSORS	16.7	3.23
246	PROPULSOR SHROUDS AND DUCTS		
247	WATER JET PROPULSORS		
250	SUPPORT SYSTEMS	72.2	40.70
251	COMBUSTION AIR SYSTEM	19.5	41.30
252	PROPULSION CONTROL SYSTEM	13.5	28.03
253	MAIN STEAM PIPING SYSTEM		
254	CONDENSERS AND AIR EJECTORS		
255	FEED AND CONDENSATE SYSTEM		
256	CIRC + COOL SEA WATER SYSTEM	10.1	15.52
258	H.P. STEAM DRAIN SYSTEM		
259	UPTAKES (INNER CASING)	29.0	54.99
260	PROPUL SUP SYS- FUEL, LUBE OIL	31.2	14.71
261	FUEL SERVICE SYSTEM	9.4	18.35
262	MAIN PROPULSION LUBE OIL SYSTEM	15.6	12.00
264	LUBE OIL HANDLING	6.2	16.00
290	SPECIAL PURPOSE SYSTEMS	20.9	11.11
298	OPERATING FLUIDS	15.6	8.00
299	REPAIR PARTS + TOOLS	5.3	20.27

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

41. WEIGHT MODULE -- ELECTRIC PLANT WEIGHT

SWBS	COMPONENT	WT-LTON	VCG-FT
====	=========	=============	============
300	ELECTRIC PLANT, GENERAL	263.4	28.10
310	ELECTRIC POWER GENERATION	44.8	18.07
311	SHIP SERVICE POWER GENERATION	44.8	18.07
312	EMERGENCY GENERATORS		
313	BATTERIES+SERVICE FACILITIES		
314	POWER CONVERSION EQUIPMENT		
320	POWER DISTRIBUTION SYS	165.8	28.02
321	SHIP SERVICE POWER CABLE	123.8	27.00
322	EMERGENCY POWER CABLE SYS		
323	CASUALTY POWER CABLE SYS		
324	SWITCHGEAR+PANELS	42.0	31.01
330	LIGHTING SYSTEM	36.2	39.20
331	LIGHTING DISTRIBUTION	20.1	38.81
332	LIGHTING FIXTURES	16.1	39.67
340	POWER GENERATION SUPPORT SYS	13.4	34.44
341	SSTG LUBE OIL		
342	DIESEL SUPPORT SYS		
343	TURBINE SUPPORT SYS	13.4	34.44
390	SPECIAL PURPOSE SYS	3.1	20.16
398	ELECTRIC PLANT OP FLUIDS	.9	18.07
399	REPAIR PARTS+SPECIAL TOOLS	2.2	21.00

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

42. WEIGHT MODULE -- COMMAND & SURVEILLANCE WEIGHT

SWBS	COMPONENT	WT-LTON	VCG-FT
400	COMMAND+SURVEILLANCE	179.1	40.51
* 410	COMMAND+CONTROL SYS	3.5	34.83
411	DATA DISPLAY GROUP		
412	DATA PROCESSING GROUP		
413	DIGITAL DATA SWITCHBOARDS		
414	INTERFACE EQUIPMENT		
415	DIGITAL DATA COMMUNICATIONS		
417	COMMAND+CONTROL ANALOG SWBD		
420	NAVIGATION SYS	13.4	54.97
430	INTERIOR COMMUNICATIONS	44.3	29.74
* 440	EXTERIOR COMMUNICATIONS	32.4	40.16
441	RADIO SYSTEMS		
442	UNDERWATER SYSTEMS		
443	VISUAL + AUDIBLE SYSTEMS		
444	TELEMETRY SYSTEMS		
445	TTY + FACSIMILE SYSTEMS		
446	SECURITY EQUIPMENT SYSTEMS		
450	SURF SURV SYS (RADAR)	8.0	74.12
* 451	SURFACE SEARCH RADAR	.1	66.36
* 452	AIR SEARCH RADAR (2D)	5.6	77.31
453	AIR SEARCH RADAR (3D)		
454	AIRCRAFT CONTROL APPROACH RADAR		
* 455	IDENTIFICATION SYSTEMS (IFF)	2.3	66.96
456	MULTIPLE MODE RADAR		
459	SPACE VEHICLE ELECTRONIC TRACKG		
460	UNDERWATER SURVEILLANCE SYSTEMS		
461	ACTIVE SONAR		
462	PASSIVE SONAR		
463	MULTIPLE MODE SONAR		
464	CLASSIFICATION SONAR		
465	BATHYTHERMOGRAPH		
470	COUNTERMEASURES	42.6	31.29
471	ACTIVE + ACTIVE/PASSIVE ECM		
472	PASSIVE ECM		
473	TORPEDO DECOYS		
* 474	DECOYS (OTHER)	1.6	70.31
475	DEGAUSSING	41.0	29.74
476	MINE COUNTERMEASURES		
480	FIRE CONTROL SYS	29.9	56.88
* 481	GUN FIRE CONTROL SYSTEMS	1.0	62.81
* 482	MISSILE FIRE CONTROL SYSTEMS	28.9	56.68
483	UNDERWATER FIRE CONTROL SYSTEMS		
484	INTEGRATED FIRE CONTROL SYSTEMS		
489	WEAPON SYSTEM SWITCHBOARDS		
490	SPECIAL PURPOSE SYS	4.9	29.74
491	ELCTRNC TEST,CHKOUT,MONITR EQPT		
492	FLIGHT CNTRL+INSTR LANDING SYS		
493	NON-COMBAT DATA PROCESSING SYS		
494	METEOROLOGICAL SYSTEMS		
495	SPEC PURPOSE INTELLIGENCE SYS		
498	C+S OPERATING FLUIDS		
499	REPAIR PARTS+SPECIAL TOOLS	4.9	29.74

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

43. WEIGHT MODULE -- AUXILIARY SYSTEMS WEIGHT

	SWBS	COMPONENT	WT-LTON	VCG-FT
	500	AUXILIARY SYSTEMS, GENERAL	887.0	26.57
	510	CLIMATE CONTROL	218.8	28.29
	511	COMPARTMENT HEATING SYSTEM	11.7	28.72
	512	VENTILATION SYSTEM	81.4	35.17
	513	MACHINERY SPACE VENT SYSTEM	14.6	38.57
	514	AIR CONDITIONING SYSTEM	103.4	21.79
	516	REFRIGERATION SYSTEM	2.4	16.22
	517	AUX BOILERS+OTHER HEAT SOURCES	5.4	25.87
	520	SEA WATER SYSTEMS	162.2	26.76
	521	FIREMAIN+SEA WATER FLUSHING SYS	92.0	26.11
	522	SPRINKLING SYSTEM	6.1	29.33
	523	WASHDOWN SYSTEM	2.7	46.65
	524	AUXILIARY SEAWATER SYSTEM		
	526	SCUPPERS+DECK DRAINS	2.0	44.18
	527	FIREMAIN ACTUATED SERV, OTHER		
	528	PLUMBING DRAINAGE	23.0	29.46
*	529	DRAINAGE+BALLASTING SYSTEM	36.4	23.82
	530	FRESH WATER SYSTEMS	34.7	26.52
	531	DISTILLING PLANT	4.7	24.30
	532	COOLING WATER	7.2	44.18
	533	POTABLE WATER	7.8	25.22
	534	AUX STEAM + DRAINS IN MACH BOX	14.9	19.44
	535	AUX STEAM + DRAINS OUT MACH BOX		
	536	AUXILIARY FRESH WATER COOLING		
	540	FUELS/LUBRICANTS,HANDLING+STORAGE	51.1	19.32
	541	SHIP FUEL+COMPENSATING SYSTEM	43.5	17.67
*	542	AVIATION+GENERAL PURPOSE FUELS	7.6	28.77
	543	AVIATION+GENERAL PURPOSE LUBO		
	544	LIQUID CARGO		
	545	TANK HEATING		
	549	SPEC FUEL+LUBRICANTS HANDL+STOW		
	550	AIR,GAS+MISC FLUID SYSTEM	84.8	28.05
	551	COMPRESSED AIR SYSTEMS	53.3	25.98
	552	COMPRESSED GASES		
	553	O2 N2 SYSTEM		
	554	LP BLOW		
	555	FIRE EXTINGUISHING SYSTEMS	31.5	31.56
	556	HYDRAULIC FLUID SYSTEM		
	557	LIQUID GASES, CARGO		
	558	SPECIAL PIPING SYSTEMS		
	560	SHIP CNTL SYS	126.9	13.92
	561	STEERING+DIVING CNTL SYS	33.6	24.30
	562	RUDDER	69.9	11.88
	565	TRIM+HEEL SYSTEMS	23.5	5.12
	568	MANEUVERING SYSTEMS		
	570	UNDERWAY REPLENISHMENT SYSTEMS	28.5	40.22
	571	REPLENISHMENT-AT-SEA SYSTEMS	16.0	43.86
	572	SHIP STORES+EQUIP HANDLING SYS	12.5	35.55
	573	CARGO HANDLING SYSTEMS		
	574	VERTICAL REPLENISHMENT SYSTEMS		
	580	MECHANICAL HANDLING SYSTEMS	102.7	40.33
	581	ANCHOR HANDLING+STOWAGE SYSTEMS	66.7	34.24
	582	MOORING+TOWING SYSTEMS	13.3	41.90
	583	BOATS,HANDLING+STOWAGE SYSTEMS	19.1	59.65
	584	MECH OPER DOOR,GATE,RAMP,TTBL SYS		
	585	ELEVATING + RETRACTING GEAR		
	586	AIRCRAFT RECOVERY SUPPORT SYS		
	587	AIRCRAFT LAUNCH SUPPORT SYSTEM		
*	588	AIRCRAFT HANDLING,SERVICING,STOWAGE	3.6	44.80

43. WEIGHT MODULE (continued)

589	MISC MECH HANDLING SYSTEMS		
590	SPECIAL PURPOSE SYSTEMS	77.4	21.96
591	SCIENTIFIC+OCEAN ENGINEERING SYS		
592	SWIMMER+DIVER SUPPORT+PROT SYS		
593	ENVIRONMENTAL POLLUTION CNTL SYS	5.4	9.10
594	SUBMARINE RESC+SALVG+SURVIVE SYS		
595	TOW,LAUNCH,HANDLE UNDERWATER SYS		
596	HANDLING SYS FOR DIVER+SUBMR VEH		
597	SALVAGE SUPPORT SYSTEMS		
598	AUX SYSTEMS OPERATING FLUIDS	67.4	22.92
599	AUX SYSTEMS REPAIR PARTS+TOOLS	4.5	22.98

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

44. WEIGHT MODULE -- OUTFIT & FURNISHINGS WEIGHT

SWBS	COMPONENT	WT-LTON	VCG-FT
600	OUTFIT+FURNISHING,GENERAL	510.2	28.81
610	SHIP FITTINGS	23.4	49.88
611	HULL FITTINGS	9.4	40.58
612	RAILS,STANCHIONS+LIFELINES	10.9	53.02
613	RIGGING+CANVAS	3.1	67.16
620	HULL COMPARTMENTATION	134.4	24.67
621	NON-STRUCTURAL BULKHEADS	43.4	32.10
622	FLOOR PLATES+GRATING	69.3	17.67
623	LADDERS	11.2	28.75
624	NON-STRUCTURAL CLOSURES	8.5	31.27
625	AIRPORTS,FIXED PORTLIGHTS,WINDOWS	2.0	55.27
630	PRESERVATIVES+COVERINGS	210.7	29.72
631	PAINTING	57.5	22.06
632	ZINC COATING		
633	CATHODIC PROTECTION	2.0	6.00
634	DECK COVERINGS	45.5	29.18
635	HULL INSULATION	58.5	34.80
636	HULL DAMPING		
637	SHEATHING	42.5	35.73
638	REFRIGERATION SPACES	4.8	20.99
639	RADIATION SHIELDING		
640	LIVING SPACES	32.2	27.85
641	OFFICER BERTHING+MESSING	7.1	39.06
642	NON-COMM OFFICER B+M	3.6	29.94
643	ENLISTED PERSONNEL B+M	17.7	23.13
644	SANITARY SPACES+FIXTURES	2.9	24.92
645	LEISURE+COMMUNITY SPACES	.9	33.61
650	SERVICE SPACES	15.7	29.69
651	COMMISSARY SPACES	6.9	33.19
652	MEDICAL SPACES	1.6	29.86
653	DENTAL SPACES		
654	UTILITY SPACES	.7	33.61
655	LAUNDRY SPACES	3.5	24.84
656	TRASH DISPOSAL SPACES	3.0	26.33
660	WORKING SPACES	42.9	32.04
661	OFFICES	5.7	29.99
662	MACH CNTL CENTER FURNISHING	1.3	23.75
663	ELECT CNTL CENTER FURNISHING	11.9	42.29
664	DAMAGE CNTL STATIONS	5.4	36.48
665	WORKSHOPS,LABS,TEST AREAS	18.7	25.47
670	STOWAGE SPACES	47.1	23.61
671	LOCKERS+SPECIAL STOWAGE	8.5	32.15
672	STOREROOMS+ISSUE ROOMS	38.6	21.74
673	CARGO STOWAGE		
690	SPECIAL PURPOSE SYSTEMS	3.7	27.31
698	OPERATING FLUIDS	.3	31.56
699	REPAIR PARTS+SPECIAL TOOLS	3.4	26.89

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

45. WEIGHT MODULE -- ARMAMENT WEIGHT

	SWBS	COMPONENT	WT-LTON	VCG-FT
	700	ARMAMENT	912.0	32.77
*	710	GUNS+AMMUNITION	13.2	69.31
	711	GUNS		
	712	AMMUNITION HANDLING		
	713	AMMUNITION STOWAGE		
	720	MISSLES+ROCKETS	893.8	32.16
*	721	LAUNCHING DEVICES	887.8	32.11
*	722	MISSILE,ROCKET,GUID CAP HANDL SYS	6.0	39.91
	723	MISSILE+ROCKET STOWAGE		
	724	MISSILE HYDRAULICS		
	725	MISSILE GAS		
	726	MISSILE COMPENSATING		
	727	MISSILE LAUNCHER CONTROL		
	728	MISSILE HEAT,COOL,TEMP CNTRL		
	729	MISSILE MONITOR,TEST,ALINEMENT		
	730	MINES		
	731	MINE LAUNCHING DEVICES		
	732	MINE HANDLING		
	733	MINE STOWAGE		
	740	DEPTH CHARGES		
	741	DEPTH CHARGE LAUNCHING DEVICES		
	742	DEPTH CHARGE HANDLING		
	743	DEPTH CHARGE STOWAGE		
	750	TORPEDOES		
	751	TORPEDO TUBES		
	752	TORPEDO HANDLING		
	753	TORPEDO STOWAGE		
	760	SMALL ARMS+PYROTECHNICS	2.3	39.24
	761	SMALL ARMS+PYRO LAUNCHING DEV	1.0	39.24
	762	SMALL ARMS+PYRO HANDLING		
	763	SMALL ARMS+PYRO STOWAGE	1.3	39.24
	770	CARGO MUNITIONS		
	772	CARGO MUNITIONS HANDLING		
	773	CARGO MUNITIONS STOWAGE		
*	780	AIRCRAFT RELATED WEAPONS	2.7	50.27
	782	AIRCRAFT RELATED WEAPONS HANDL		
	783	AIRCRAFT RELATED WEAPONS STOW		
	790	SPECIAL PURPOSE SYSTEMS		
	792	SPECIAL WEAPONS HANDLING		
	793	SPECIAL WEAPONS STOWAGE		
	797	MISC ORDINANCE SPACES		
	798	ARMAMENT OPERATING FLUIDS		
	799	ARMAMENT REPAIR PART+TOOLS		

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

46. WEIGHT MODULE -- LOADS WEIGHT (FULL LOAD CONDITION)

	SWBS	COMPONENT	WT-LTON	VCG-FT
	F00	LOADS	1869.9	20.34
	F10	SHIPS FORCE	20.6	32.34
	F11	OFFICERS	3.0	32.34
	F12	NON-COMMISSIONED OFFICERS	2.2	32.34
	F13	ENLISTED MEN	15.4	32.34
	F14	MARINES		
	F15	TROOPS		
	F16	AIR WING PERSONNEL		
	F19	OTHER PERSONNEL		
	F20	MISSION RELATED EXPENDABLES+SYS	611.0	35.56
*	F21	SHIP AMMUNITION	604.6	35.30
	F22	ORD DEL SYS AMMO		
*	F23	ORD DEL SYS (AIRCRAFT)	6.4	59.77
	F24	ORD REPAIR PARTS (SHIP)		
	F25	ORD REPAIR PARTS (ORD)		
	F26	ORD DEL SYS SUPPORT EQUIP		
	F29	SPECIAL MISSION RELATED SYS		
	F30	STORES	28.7	24.26
	F31	PROVISIONS+PERSONNEL STORES	23.4	23.68
	F32	GENERAL STORES	5.3	26.82
	F33	MARINES STORES (SHIPS COMPLEM)		
	F39	SPECIAL STORES		
	F40	LIQUIDS, PETROLEUM BASED	1179.7	12.52
	F41	DIESEL FUEL MARINE	1108.1	12.53
*	F42	JP-5	64.4	13.00
	F43	GASOLINE		
	F44	DISTILLATE FUEL		
	F45	NAVY STANDARD FUEL OIL (NSFO)		
	F46	LUBRICATING OIL	7.2	6.33
	F49	SPECIAL FUELS AND LUBRICANTS		
	F50	LIQUIDS, NON-PETRO BASED	29.9	6.10
	F51	SEA WATER		
	F52	FRESH WATER	29.9	6.10
	F53	RESERVE FEED WATER		
	F54	HYDRAULIC FLUID		
	F55	SANITARY TANK LIQUID		
	F56	GAS (NON FUEL TYPE)		
	F59	MISC LIQUIDS, NON-PETROLEUM		
	F60	CARGO		
	F61	CARGO, ORDINANCE + DELIVERY SYS		
	F62	CARGO, STORES		
	F63	CARGO, FUELS + LUBRICANTS		
	F64	CARGO, LIQUIDS, NON-PETROLEUM		
	F65	CARGO, CRYOGENIC+LIQUEFIED GAS		
	F66	CARGO, AMPHIBIOUS ASSAULT SYS		
	F67	CARGO, GASES		
	F69	CARGO, MISCELLANEOUS		
	M24	FUTURE GROWTH MARGIN		

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

47. WEIGHT MODULE -- WEIGHT AND KG MODIFICATION SUMMARY

ROW	P+A NAME / WT KEYS	ORIGINAL WT, LTON	WT CHNG, LTON	RESULTNT WT, LTON	ORIGINAL KG, FT	KG CHNG, FT	RESULTNT KG, FT
57	STEEL LANDING PAD [ON HULL] SH-60 CAPABLE						
	W110	1093.5	10.7	1104.2	20.2	39.2	20.4
25	VLS MAGAZINE ARMOR [LEVEL III HY-80]						
	W164	0.0	21.1		UNKNOWN	34.8	
26	VLS MAGAZINE ARMOR [LEVEL III HY-80]						
			21.1			34.8	
27	VLS MAGAZINE ARMOR [LEVEL III HY-80]						
			21.1			33.1	
28	VLS MAGAZINE ARMOR [LEVEL III HY-80]						
			21.1			33.1	
29	VLS MAGAZINE ARMOR [LEVEL III HY-80]						
			21.1			33.8	
30	VLS MAGAZINE ARMOR [LEVEL III HY-80]						
			21.1	126.6		33.8	33.9
47	1/4 OF DD 963 CIC COMMAND AND DECISION						
	W410	0.0	3.5	3.5	UNKNOWN	34.8	34.8
37	DDG51 EXCOMM						
	W440	0.0	32.4	32.4	UNKNOWN	40.2	40.2
38	SPS-64 SURFACE SEARCH & NAVIGATION RADAR						
	W451	0.0	0.1	0.1	UNKNOWN	66.4	66.4
39	MK-23 TARGET ACQUISITION SYSTEM [NSSMS TAS]						
	W452	0.0	5.6	5.6	UNKNOWN	77.3	77.3
40	MK XII AIMS IFF						
	W455	0.0	2.3	2.3	UNKNOWN	67.0	67.0
41	SLQ-32(V)3 MK-36 DLS W/4 LAUNCHERS						
	W474	0.0	1.6	1.6	UNKNOWN	70.3	70.3
49	MK-16 CIWS WEAPON CONTROL SYSTEM						
	W481	0.0	1.0	1.0	UNKNOWN	62.8	62.8
13	VLS WEAPON CONTROL SYSTEM						
	W482	0.0	0.7		UNKNOWN	37.0	
14	VLS WEAPON CONTROL SYSTEM						
			0.7			37.0	
15	VLS WEAPON CONTROL SYSTEM						
			0.7			35.3	
16	VLS WEAPON CONTROL SYSTEM						
			0.7			35.3	
17	VLS WEAPON CONTROL SYSTEM						
			0.7			36.0	
18	VLS WEAPON CONTROL SYSTEM						
			0.7			36.0	
43	MK-91 NSSMS MFCS						
			11.2			79.4	
44	MK-91 NSSMS MFCS (ADD'L MK76 DIRECTOR)						
			2.3			79.4	
45	TOMAHAWK WEAPON CONTROL SYSTEM						
			5.6			37.0	
46	TOMAHAWK WEAPON CONTROL SYSTEM						
			5.6	28.9		37.0	56.7
31	VLS MAGAZINE DEWATERING SYSTEM						
	W529	18.4	3.0		-147.3	34.0	
32	VLS MAGAZINE DEWATERING SYSTEM						
			3.0			34.0	
33	VLS MAGAZINE DEWATERING SYSTEM						
			3.0			32.3	
34	VLS MAGAZINE DEWATERING SYSTEM						
			3.0			32.3	

47. WEIGHT MODULE (continued)

35	VLS MAGAZINE DEWATERING SYSTEM						
			3.0			33.0	
36	VLS MAGAZINE DEWATERING SYSTEM						
			3.0	36.4		33.0	23.8
55	LAMPS III HELO IN-FLIGHT REFUELING SYSTEM [HIFR]						
	W542	0.0	7.6	7.6	UNKNOWN	28.8	28.8
56	LAMPS III HELO SECURING SYSTEM						
	W588	0.0	3.6	3.6	UNKNOWN	44.8	44.8
48	2X MK-16 20MM CIWS [VULCAN-PHALANX] + WORKSHOPS						
	W710	0.0	13.2	13.2	UNKNOWN	69.3	69.3
1	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
	W721	0.0	148.0		UNKNOWN	33.0	
2	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			148.0			33.0	
3	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			148.0			31.3	
4	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			148.0			31.3	
5	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			148.0			32.0	
6	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			148.0	887.8		32.0	32.1
19	VLS WEAPON HANDLING SYSTEM						
	W722	0.0	1.0		UNKNOWN	40.8	
20	VLS WEAPON HANDLING SYSTEM						
			1.0			40.8	
21	VLS WEAPON HANDLING SYSTEM						
			1.0			39.1	
22	VLS WEAPON HANDLING SYSTEM						
			1.0			39.1	
23	VLS WEAPON HANDLING SYSTEM						
			1.0			39.8	
24	VLS WEAPON HANDLING SYSTEM						
			1.0	6.0		39.8	39.9
53	LAMPS III HELO REARM + MAGAZINE						
	W780	0.0	2.7	2.7	UNKNOWN	50.3	50.3
7	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
	WF21	0.0	99.0		UNKNOWN	35.6	
8	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			99.0			35.6	
9	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			99.0			33.9	
10	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			99.0			33.9	
11	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			99.0			34.6	
12	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VLASROC						
			99.0			34.6	
42	MK-36 DLS SRBOC CANNISTERS [100 ROUNDS]						
			2.2			70.3	
50	MK-16 20MM CIWS AMMO [16000 ROUNDS]						
			8.4	604.6		68.3	35.3
52	LAMPS III SH-60B HELICOPTER & HANGER						
	WF23	0.0	6.4	6.4	UNKNOWN	59.8	59.8
54	LAMPS III AVIATION FUEL [JP-5]						
	WF42	0.0	64.4	64.4	UNKNOWN	13.0	13.0

48. WEIGHT MODULE -- P+A WEIGHTS AND VCGS

ROW	P+A WT KEY	WEIGHT ADD	WEIGHT FAC,LTON	VCG KEY	VCG ADD,FT	VCG FAC
57	STEEL LANDING PAD [ON HULL] SH-60 CAPABL					
	W110	10.70	0.00	D20	0.20	1.00
25	VLS MAGAZINE ARMOR [LEVEL III HY-80]					
	W164	21.10	0.00	D6.5	-10.00	1.00
26	VLS MAGAZINE ARMOR [LEVEL III HY-80]					
	W164	21.10	0.00	D6.5	-10.00	1.00
27	VLS MAGAZINE ARMOR [LEVEL III HY-80]					
	W164	21.10	0.00	D10	-10.00	1.00
28	VLS MAGAZINE ARMOR [LEVEL III HY-80]					
	W164	21.10	0.00	D10	-10.00	1.00
29	VLS MAGAZINE ARMOR [LEVEL III HY-80]					
	W164	21.10	0.00	D15	-10.00	1.00
30	VLS MAGAZINE ARMOR [LEVEL III HY-80]					
	W164	21.10	0.00	D15	-10.00	1.00
47	1/4 OF DD 963 CIC COMMAND AND DECISION					
	W410	3.50	0.00	D6.5	-10.00	1.00
37	DDG51 EXCOMM					
	W440	32.39	0.00	MAST	-25.70	1.00
38	SPS-64 SURFACE SEARCH & NAVIGATION RADAR					
	W451	0.13	0.00	MAST	0.50	1.00
39	MK-23 TARGET ACQUISITION SYSTEM [NSSMS T					
	W452	5.55	0.00	D3	29.00	1.00
40	MK XII AIMS IFF					
	W455	2.33	0.00	MAST	1.10	1.00
41	SLQ-32(V)3 MK-36 DLS W/4 LAUNCHERS					
	W474	1.63	0.00	D3	22.00	1.00
49	MK-16 CIWS WEAPON CONTROL SYSTEM					
	W481	1.00	0.00	D3	14.50	1.00
13	VLS WEAPON CONTROL SYSTEM					
	W482	0.70	0.00	D6.5	-7.80	1.00
14	VLS WEAPON CONTROL SYSTEM					
	W482	0.70	0.00	D6.5	-7.80	1.00
15	VLS WEAPON CONTROL SYSTEM					
	W482	0.70	0.00	D10	-7.80	1.00
16	VLS WEAPON CONTROL SYSTEM					
	W482	0.70	0.00	D10	-7.80	1.00
17	VLS WEAPON CONTROL SYSTEM					
	W482	0.70	0.00	D15	-7.80	1.00
18	VLS WEAPON CONTROL SYSTEM					
	W482	0.70	0.00	D15	-7.80	1.00
43	MK-91 NSSMS MFCS					
	W482	11.20	0.00	D3	31.10	1.00
44	MK-91 NSSMS MFCS (ADD'L MK76 DIRECTOR)					
	W482	2.30	0.00	D3	31.10	1.00
45	TOMAHAWK WEAPON CONTROL SYSTEM					
	W482	5.61	0.00	D6.5	-7.80	1.00
46	TOMAHAWK WEAPON CONTROL SYSTEM					
	W482	5.61	0.00	D6.5	-7.80	1.00
31	VLS MAGAZINE DEWATERING SYSTEM					
	W529	3.00	0.00	D6.5	-10.80	1.00
32	VLS MAGAZINE DEWATERING SYSTEM					
	W529	3.00	0.00	D6.5	-10.80	1.00
33	VLS MAGAZINE DEWATERING SYSTEM					
	W529	3.00	0.00	D10	-10.80	1.00
34	VLS MAGAZINE DEWATERING SYSTEM					
	W529	3.00	0.00	D10	-10.80	1.00
35	VLS MAGAZINE DEWATERING SYSTEM					
	W529	3.00	0.00	D15	-10.80	1.00

48. WEIGHT MODULE (continued)

36	VLS MAGAZINE DEWATERING SYSTEM					
	W529	3.00	0.00	D15	-10.80	1.00
55	LAMPS III HELO IN-FLIGHT REFUELING SYSTE					
	W542	7.60	0.00	D15	-15.00	1.00
56	LAMPS III HELO SECURING SYSTEM					
	W588	3.60	0.00	D20	5.80	1.00
48	2X MK-16 20MM CIWS [VULCAN-PHALANX] + WO					
	W710	13.20	0.00	D3	21.00	1.00
1	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 1					
	W721	147.96	0.00	D6.5	-11.80	1.00
2	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 1					
	W721	147.96	0.00	D6.5	-11.80	1.00
3	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 1					
	W721	147.96	0.00	D10	-11.80	1.00
4	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 1					
	W721	147.96	0.00	D10	-11.80	1.00
5	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 1					
	W721	147.96	0.00	D15	-11.80	1.00
6	8X MK41 VLS 61-CELL W/7TMKWK + 45SM2 + 1					
	W721	147.96	0.00	D15	-11.80	1.00
19	VLS WEAPON HANDLING SYSTEM					
	W722	1.00	0.00	D6.5	-4.00	1.00
20	VLS WEAPON HANDLING SYSTEM					
	W722	1.00	0.00	D6.5	-4.00	1.00
21	VLS WEAPON HANDLING SYSTEM					
	W722	1.00	0.00	D10	-4.00	1.00
22	VLS WEAPON HANDLING SYSTEM					
	W722	1.00	0.00	D10	-4.00	1.00
23	VLS WEAPON HANDLING SYSTEM					
	W722	1.00	0.00	D15	-4.00	1.00
24	VLS WEAPON HANDLING SYSTEM					
	W722	1.00	0.00	D15	-4.00	1.00
53	LAMPS III HELO REARM + MAGAZINE					
	W780	2.72	0.00	D15	6.50	1.00
7	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VL					
	WF21	99.00	0.00	D6.5	-9.20	1.00
8	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VL					
	WF21	99.00	0.00	D6.5	-9.20	1.00
9	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VL					
	WF21	99.00	0.00	D10	-9.20	1.00
10	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VL					
	WF21	99.00	0.00	D10	-9.20	1.00
11	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VL					
	WF21	99.00	0.00	D15	-9.20	1.00
12	MISSILES: 7TMKWK + 45SM2 + 16VLSS + 5VL					
	WF21	99.00	0.00	D15	-9.20	1.00
42	MK-36 DLS SRBOC CANNISTERS [100 ROUNDS]					
	WF21	2.18	0.00	D3	22.00	1.00
50	MK-16 20MM CIWS AMMO [16000 ROUNDS]					
	WF21	8.39	0.00	D3	20.00	1.00
52	LAMPS III SH-60B HELICOPTER & HANGER					
	WF23	6.40	0.00	D15	16.00	1.00
54	LAMPS III AVIATION FUEL [JP-5]					
	WF42	64.40	0.00	BL	13.00	1.00

49. SPACE MODULE -- SUMMARY

COLL PROTECT SYS-PARTIAL SONAR DOME-NONE UNIT COMMANDER-NONE

FULL LOAD WT, LTON	8416.8	HAB STANDARD FAC	0.260
TOTAL CREW ACC	201.	PASSWAY MARGIN FAC	0.000
HULL AVG DECK HT, FT	11.17	AC MARGIN FAC	0.000
MR VOLUME, FT3	91346.	SPACE MARGIN FAC	0.000

	PAYLOAD REQUIRED	AREA FT2 TOTAL REQUIRED	TOTAL AVAILABLE	VOL FT3 TOTAL ACTUAL
DKHS ONLY	1358.0	7295.7	11327.6	116073.
HULL OR DKHS	16100.0	66208.1	78264.2	1033448.
TOTAL	17458.0	73503.8	89591.8	1149522.

SSCS GROUP	TOTAL AREA FT2	DKHS AREA FT2	PERCENT TOTAL AREA
1. MISSION SUPPORT	19244.1	2086.6	26.2
2. HUMAN SUPPORT	13780.6	839.5	18.7
3. SHIP SUPPORT	37561.7	3160.5	51.1
4. SHIP MOBILITY SYSTEM	2917.3	1209.2	4.0
5. UNASSIGNED			0.0
TOTAL	73503.8	7295.7	100.0

50. SPACE MODULE -- MISSION SUPPORT AREA

SSCS	GROUP	TOTAL AREA FT2	DKHS AREA FT2
1.	MISSION SUPPORT	19244.1	2086.6
1.1	COMMAND,COMMUNICATION+SURV	3263.5	871.7
1.11	EXTERIOR COMMUNICATIONS	1365.0	95.0
*1.111	RADIO	1365.0	95.0
1.112	UNDERWATER SYSTEMS		
1.12	SURVEILLANCE SYS	70.0	70.0
*1.121	SURFACE SURV (RADAR)	70.0	70.0
1.122	UNDERWATER SURV (SONAR)		
1.13	COMMAND+CONTROL	1006.7	706.7
*1.131	COMBAT INFO CENTER	300.0	
1.132	CONNING STATIONS	706.7	706.7
1.1321	PILOT HOUSE	626.7	626.7
1.1322	CHART ROOM	80.0	80.0
1.14	COUNTERMEASURES		
1.141	ELECTRONIC		
1.142	TORPEDO		
1.143	MISSILE		
1.15	INTERIOR COMMUNICATIONS	793.2	
1.16	ENVIRONMENTAL CNTL SUP SYS	28.6	
1.2	WEAPONS	15679.0	1193.0
*1.21	GUNS	1042.0	1042.0
*1.22	MISSILES	14502.0	120.0
*1.23	ROCKETS	135.0	31.0
1.24	TORPEDOS		
1.25	DEPTH CHARGES		
1.26	MINES		
1.27	SPECIAL WEAPONS		
1.3	AVIATION	44.0	
1.31	AVIATION LAUNCHING+RECOVERY		
1.311	LAUNCHING+RECOVERY AREAS		
1.312	LAUNCHING+RECOVERY EQUIP		
1.33	AIRCRAFT HANDLING		
1.34	AIRCRAFT STOWAGE		
1.36	AVIATION MAINTENANCE		
1.37	AVIATION ORDNANCE		
1.372	CONTROL		
1.373	HANDLING		
1.374	STOWAGE		
*1.38	AVIATION FUEL SYS	44.0	
1.39	AVIATION STORES		
1.6	INTERMEDIATE MAINT FAC		
1.641	STOWAGE-WEAPONS		
1.7	FLAG FACILITIES		
1.73	HANDLING		
1.74	STOWAGE		
1.8	SPECIAL MISSIONS		
1.9	SM ARMS,PYRO+SALU BAT	257.6	21.8
1.911	SM ARMS (LOCKER)	95.4	
1.921	PYROTECHNICS (LOCKER)	21.8	21.8
1.932	SALUTING BAT (MAGAZINE)	32.2	
1.95	LANDING FORCE EQUIP	108.1	

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

51. SPACE MODULE -- HUMAN SUPPORT AREA

SSCS	GROUP	TOTAL AREA FT2	DKHS AREA FT2
2.	HUMAN SUPPORT	13780.6	839.5
2.1	LIVING	8360.7	796.5
2.11	OFFICER LIVING	2501.3	796.5
2.111	BERTHING	2230.4	695.7
2.1111	SHIP OFFICER	2230.4	695.7
2.1115	FLAG OFFICER		
2.112	SANITARY	270.9	100.8
2.1121	SHIP OFFICER	270.9	100.8
2.1125	FLAG OFFICER		
2.12	CPO LIVING	841.1	
2.121	BERTHING	664.0	
2.122	SANITARY	177.0	
2.13	CREW LIVING	4844.1	
2.131	BERTHING	4158.0	
2.132	SANITARY	686.1	
2.1332	RECREATION (LIBRARY)		
2.14	GENERAL SANITARY FACILITIES	110.0	
2.141	LADIES RETIRING RM	80.0	
2.142	BRIDGE WASHROOM+WC	15.0	
2.143	DECK WASHROOM+WC	15.0	
2.15	SHIP RECREATION FAC	64.3	
2.152	MOTION PIC FILM+EQUIP	40.2	
2.153	PHYSICAL FITNESS	24.1	
2.154	BAND EQUIP RM		
2.2	COMMISSARY	3832.2	
2.21	FOOD SERVICE	2350.1	
2.211	OFFICER (MESS+LOUNGE)	683.0	
2.212	CPO (MESS+LOUNGE)	540.8	
2.213	CREW (MESS+LOUNGE)	1126.3	
2.22	COMMISSARY SERVICE SPACES	1032.5	
2.23	FOOD STORAGE+ISSUE	449.5	
2.231	CHILL PROVISIONS	164.7	
2.232	FROZEN PROVISIONS	59.6	
2.233	DRY PROVISIONS	225.2	
2.234	ISSUE		
2.3	MEDICAL+DENTAL (MEDICAL)	300.0	
2.4	GENERAL SERVICES	793.6	
2.41	SHIP STORE SPACES	258.1	
2.411	SHIP STORE	111.0	
2.412	CLOTHING+SM STORES ISSUE	17.8	
2.415	SHIP STORE STORES	129.3	
2.42	LAUNDRY FACILITIES	387.5	
2.43	DRY CLEANING+TAILOR SHOP		
2.44	BARBER SERVICE	80.0	
2.46	POSTAL SERVICE	56.0	
2.47	BRIG		
2.48	RELIGIOUS	12.0	
2.5	PERSONNEL STORES	170.7	43.0
2.51	BAGGAGE	39.3	
2.52	WARDROOM STOREROOM	13.0	13.0
2.53	CPO STORE ROOM	8.5	
2.54	COMMANDING OFFICER STRM	40.0	
2.55	FOUL WEATHER GEAR (LOCKER)	30.0	30.0
2.57	FOLDING CHAIR STOREROOM	40.0	
2.6	CBR PROTECTION	140.2	
2.7	LIFESAVING (LIFEJACKETS)	20.0	
2.9	POLLUTION CNTL SYS (SEWAGE)	163.2	

S2. SPACE MODULE -- SHIP SUPPORT AREA

SSCS	GROUP	TOTAL AREA FT2	DKHS AREA FT2
3.	SHIP SUPPORT	37561.7	3160.5
3.1	SHIP CNTL SYS(STEERING+DIVING)	931.3	
3.2	DAMAGE CNTL	757.6	
3.21	DAMAGE CNTL CENTRAL		
3.22	REPAIR STATIONS	419.6	
3.25	FIRE FIGHTING	338.0	
3.3	SHIP ADMINISTRATION	2241.6	
3.4	AUXILIARY MACHINERY	15319.9	1419.9
3.41	ENGINEERING AUX	3546.3	1419.9
3.411	A/C+REFRIGERATION	2871.5	1419.9
3.4111	A/C (INC VENT)	2773.2	1419.9
3.4112	REFRIGERATION	98.3	
3.417	PUMP+COMPRESSOR RM	674.8	
3.42	DECK AUXILIARIES	889.0	
3.421	ANCHOR HANDLING	486.7	
3.422	LINE HANDLING	402.3	
3.4X	AUXILIARY MACHINERY DELTA	10884.6	
3.5	ELECTRICAL	129.2	
3.51	POWER GENERATION		
3.511	SHIP SERVICE POWER GEN		
3.512	EMERGENCY GENERATORS		
3.514	400 HERTZ		
3.52	PWR DIST+CNTL	4.2	
3.54	DEGAUSSING	125.0	
3.6	SHIP MAINTENANCE	1573.0	
3.61	ENGINEERING DEPT	1154.7	
3.611	AUX (FILTER CLEANING)	90.0	
3.612	ELECTRICAL	229.9	
3.613	MECH (GENERAL WK SHOP)	774.8	
3.614	TEST LAB	60.0	
3.615	NUCLEONICS		
3.62	OPERATIONS DEPT (ELECT SHOP)	210.3	
3.63	WEAPONS DEPT (ORDNANCE SHOP)	137.9	
3.64	DECK DEPT (CARPENTER SHOP)	70.0	
3.7	STOREROOMS+ISSUE RMS	4588.3	526.8
3.71	SUPPY DEPT	2241.9	
3.711	HAZARDOUS MATL (FLAM LIQ)	229.9	
3.712	SPECIAL CLOTHING	75.9	
3.713	GEN USE CONSUM+REPAIR PART	1221.1	
3.714	HANDLING(STORE CONV TRUNK)	714.9	
3.72	ENGINEERING DEPT	574.8	
3.73	OPERATIONS DEPT	290.8	80.5
3.74	DECK DEPT (BOATSWAIN STORES)	1480.9	446.3
3.8	ACCESS (INTERIOR-NORMAL)	12020.9	1213.8

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

53. SPACE MODULE -- SHIP MOBILITY SYSTEM AREA

SSCS	GROUP	TOTAL AREA FT2	DKHS AREA FT2
4.	SHIP MOBILITY SYSTEM	2917.3	1209.2
4.1	PROPULSION SYSTEM	2917.3	1209.2
4.11	STEAM (CONVENTIONAL)		
4.112-3	COMBUSTION AIR-EXHAUST		
4.114	CONTROL		
4.12	STEAM (NUCLEAR)		
4.122-3	COMBUSTION AIR-EXHAUST		
4.124	CONTROL		
4.13	DIESEL		
4.132	COMBUSTION AIR		
4.133	EXHAUST		
4.134	CONTROL		
4.14	GAS TURBINE	2917.3	1209.2
4.142	COMBUSTION AIR	806.9	526.0
4.143	EXHAUST	1170.4	683.2
4.144	CONTROL	940.0	
4.3	FUEL-NUCLEAR (CORE REMOVAL)		

* DENOTES INCLUSION OF PAYLOAD OR ADJUSTMENTS

54. SPACE MODULE -- REQUIRED TANKAGE

POLLUTION CNTRL IND-PRESENT

ENDURANCE FUEL, FT3	46873.
AVIATION FUEL, FT3	2840.
FRESH WATER, FT3	1076.
SEWAGE, FT3	403.
WASTE OIL WATER, FT3	937.
CLEAN BALLAST, FT3	0.
TANKAGE MARGIN, FT3	0.
TANKAGE VOL REQ, FT3	52129.

55. COST ANALYSIS -- WARNINGS

** WARNING - COST ANALYSIS ** (W-DEFAULTVALUES-CSTMPL)
THE FOLLOWING PARAMETERS WERE PROVIDED DEFAULT VALUES:

INFLATION RATE ARRAY	LEARNING RATE
FUEL COST	PAYLOAD T+E COST
LEAD PAYLOAD COST	FOLLOW PAYLOAD COST
ANNUAL TRNG ORD COST	PAYLOAD FUEL RATE
PROFIT FRAC	SERVICE LIFE
ANNUAL OPERATING HRS	TECH ADV COST
ADDL FACILITY COST	DEFERRED MMHRS REQ
UNREP UNIT CAPACITY	UNREP UNIT COST
UNREP O+S COST	KN FACTOR ARRAY
SHIP FUEL RATE	

NOTE-THIS INTERIM MODULE PROVIDES GUIDANCE FOR DECISIONS REGARDING SHIP DESIGN TRADEOFFS AND COMPARATIVE EVALUATIONS. REQUESTS FOR ESTIMATES OF SHIP COSTS FOR BUDGETARY PURPOSES SHOULD BE DIRECTED TO NAVSEA.

56. COST ANALYSIS -- SUMMARY

YEAR $	1992.	NO OF SHIPS ACQUIRED	10.
INFLATION ESCALATION FAC	2.149	SERVICE LIFE, YR	30.0
LEARNING RATE	0.970	ANNUAL OPERATING HRS	2500.0
FUEL COST, $/GAL	2.579	MILITARY P/L, LTON	1798.3
PAYLOAD FUEL RATE, LTON/HR	0.33	LIGHTSHIP WT, LTON	6546.9
SHIP FUEL RATE, LTON/HR	2.63	FULL LOAD WT, LTON	8416.8

COST ITEM	COSTS(MILLIONS OF DOLLARS) TOT SHIP	+ PAYLOAD	= TOTAL
LEAD SHIP	1083.4	1319.7*	2403.1
FOLLOW SHIP	502.4	1158.5*	1660.9
AVG ACQUISITION COST/SHIP(10 SHIPS)	483.1	1174.6*	1657.7
LIFE CYCLE COST/SHIP(30 YEARS)			4643.2
TOTAL LIFE CYCLE COST(30 YEARS)			46431.9
DISCOUNTED LIFE CYCLE COST/SHIP			342.4**
DISCOUNTED TOTAL LIFE CYCLE COST			3424.0**

*ESTIMATED VALUE
**DISCOUNTED AT 10 PERCENT

57. COST ANALYSIS -- UNIT ACQUISITION COSTS

SWBS GROUP		UNITS	INPUTS	KN FACTORS	LEAD SHIP COSTS $K	FOLLOW SHIP COSTS $K
100	HULL STRUCTURE	LTON	3402.0	1.00	38870.	36537.
200	PROPULSION PLANT	HP	52800.0	2.35	61350.	57669.
300	ELECTRIC PLANT	LTON	263.4	1.00	25727.	24183.
400	COMMAND+SURVEILLANCE	LTON	179.1	3.15	18063.	16979.
500	AUX SYSTEMS	LTON	887.0	1.53	62919.	59144.
600	OUTFIT+FURNISHINGS	LTON	510.2	1.00	28116.	26429.
700	ARMAMENT	LTON	912.0	1.00	15033.	14131.
	MARGIN	LTON	0.0		0.	0.
800	DESIGN+ENGINEERING			26.06	392992.	43425.
900	CONSTRUCTION SERVICES			4.25	62624.	58866.
	TOTAL CONSTRUCTION COST				705694.	337364.

	LEAD	FOLLOW
CONSTRUCTION COST	705694.	337364.
PROFIT(15.0 PERCENT OF CONSTRUCTION COST)	105854.	50605.
PRICE	811548.	387969.
CHANGE ORDERS(12/8 PERCENT OF PRICE)	97386.	31037.
NAVSEA SUPPORT(2.5 PERCENT OF PRICE)	20289.	9699.
POST DELIVERY CHARGES(5 PERCENT OF PRICE)	40577.	19398.
OUTFITTING(4 PERCENT OF PRICE)	32462.	15519.
H/M/E + GROWTH(10 PERCENT OF PRICE)	81155.	38797.
TOTAL SHIP COST	1083417.	502419.
ESTIMATED PAYLOAD COST	1319714.	1158490.
SHIP PLUS PAYLOAD COST	2403131.	1660909.

ADJUSTED FIRST UNIT SHIP COST, $K 534488.6
COMBAT SYSTEM WEIGHT, LTON 1798.3
PROPULSION SYSTEM WEIGHT, LTON 393.3
ADJUSTED FIRST UNIT SHIP COST EQUALS
FOLLOW SHIP TOTAL COST DIVIDED BY 0.940

58. COST ANALYSIS -- LIFE CYCLE COSTS

IOC YEAR	2010.	PAYLOAD FUEL RATE, LTON/HR	0.33
R+D PROGRAM LENGTH, YRS	5.	SHIP FUEL RATE, LTON/HR	2.63
NUMBER OF SHIPS ACQUIRED	10.	TECH ADV COST, $M	0.00
SERVICE LIFE, YRS	30.	ADDL FACILITY COST, $M	0.00
NO OF OFFICERS/SHIP	17.	DEFERRED MMHRS REQ, HR/WK	0.
NO OF ENLISTED MEN/SHIP	165.	PRODUCTION RATE, SHIPS/YR	2.00

30 - YEAR SYSTEMS COST
(MILLIONS OF YEAR 1992 DOLLARS)

COST ELEMENT	SHIP NONREC	PAYLOAD NONREC	OTHER NONREC	TOTAL NONREC	SYSTEM RECUR	TOTAL SYSTEM
R+D TOTAL	1814.	266.	0.	2080.		2080.
DESIGN+DEVELMNT	440.		0.	440.		440.
TEST+EVALUATION	1374.	266.	0.	1640.		1640.
INVESTMENT	5217.	15622.	17.	20856.		20856.
EQUIPMENT	5072.	14095.		19167.		19167.
PRIME	4831.	11746.		16577.		16577.
SUPPORT	242.	2349.		2591.		2591.
FACILITIES			0.	0.		0.
INITIAL SPARES	145.	1527.		1672.		1672.
ASSOCIATED SYS			17.	17.		17.
OPERATIONS+SUPPRT					24106.	24106.
PERSONNEL					1515.	1515.
OPERATIONS					2742.	2742.
MAINTENANCE					5132.	5132.
ENERGY					1698.	1698.
REPL SPARES					10867.	10867.
MAJOR SUPPORT					2091.	2091.
ASSOCIATED SYS					61.	61.
LESS RESIDUAL VALUE						610.
LIFE CYCLE TOTAL SYSTEMS COST						46432.
DISCOUNTED AT 10 PERCENT						3424.

COST PER VEHICLE-UNDISCOUNTED 4643.
COST PER VEHICLE-DISCOUNTED 342.

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